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Understanding the heterogeneity of cooperation on innovation: Firm-level evidence from Europe*

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Abstract

Innovation is new combination of productive means that are internal or external to a firm. Arrangements to cooperate on innovation facilitate access to these external sources of knowledge. Using large micro datasets from the Third and Fourth Community Innovation Surveys in sixteen European countries, including nine new EU members, we examine the heterogeneity of relationships between various characteristics of firms, given by size, ownership or capabilities, and their propensity to cooperate on innovation with domestic as compared to foreign partners, with different types of organizations and how these patterns differ across countries. Econometric estimates of univariate, multivariate and multinomial probit (or logit) models indicate differences between domestic and foreign cooperation, but not between the various types of partners. Strong differences have been found along the level of economic development. Size of the country and openness to globalization proved relevant for explaining cooperation of firms on innovation abroad. Nevertheless, the results reveal that the context matters for interpretation of the cooperation variables themselves, because some of these arrangements may signal limited internal capabilities of firms, rather than virtuous systemic interactions, which complicates comparative studies of this data.

Keywords: Innovation; cooperation; globalization; Community Innovation Survey; Europe.

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1. Introduction

Innovation requires new combination of productive means. Some of them are inside the firm, while others need to be obtained externally. A purely "off-the shelf" purchase of some of these external resources is not efficient, because transfer of knowledge often requires interactive learning between users and producers (von Hippel 1976, Lundvall 1988). Firms are not islands separated by deep waters of market transactions, but are linked together in patterns of cooperation, especially as far as the development of new products and processes is concerned (Richardson 1972). Arrangements to cooperate on innovation facilitate access to this external knowledge, offering opportunities for sharing complementary resources with other organizations, spreading risks of the innovative ventures across partners and jointly overcoming obstacles along the route (Gulati 1998, Sachwald 1998), hence making firms more likely to come out with the new combinations.

Availability of direct evidence on innovation cooperation from the Community Innovation Survey triggered a growing body of empirical research on this topic (see for example Arora and Gambardella 1994, Colombo 1995, Veugelers 1997, Nooteboom 1999, Cassiman and Veugelers 2002, Tether 2002, Miotti and Sachwald 2003, Becker and Dietz 2004, Belderbos et al. 2004 and 2006, Knell and Srholec 2004, Negassi 2004, Abramovsky et al. 2009, Lööf 2009 and Srholec 2009a), which is increasingly conducted by using advanced econometric methods on micro data. As a result, there is now fairly extensive empirical literature on the cooperative behaviour of firms in the innovation process. But there also remain a host of rarely examined topics that are essential to explore for formulating effective innovation policies in context of the enlarged, globalized and challenged European community.

Admittedly, there is too little evidence on cooperation with foreign partners, except perhaps of Knell and Srholec (2004), Lööf (2009) and Srholec (2009a), and therefore on the effects of organization and market proximity abroad, which is surprising given the fact that the literature on strategic alliances has shown that international collaboration on innovation is a prominent aspect of globalization (Archibugi and Michie 1995, Narual and Hagedoorn 1999 and Hagedoorn 2002). Some of the papers considered differences between types of the partner organization, such as Cassiman and Veugelers (2002) or Belderbos et al. (2004, 2006), though this literature is rather thin too. So far very little has been done to econometrically compare patterns of innovation cooperation across countries, because most of the existing studies have been limited to evidence from a single or a small number of national datasets, only except of the recent papers by Abramovsky et al. (2009) and Srholec (2009a), which prevents us from deriving broader policy recommendations from the results.

The aim of this paper is to contribute to this debate by addressing these relatively neglected topics. Using large micro datasets from sixteen countries from the Third and Fourth Community Innovation Surveys, including nine new EU members, we econometrically examine heterogeneity of the relationship between various characteristics of firms, given by size, ownership or capabilities, and their propensity to cooperate on innovation with domestic as compared to foreign partners, with different types of organizations and how these patterns differ across countries. Section 2 provides a brief discussion of the key issues. Section 3 presents the micro data and explains measures of the national framework conditions. Section 4 explores descriptive evidence on the cooperation variables. Section 5 delineates the regression models, debates methodological problems and presents results of the univariate, multivariate and multinomial, including multilevel, probit (or logit) econometric estimates. Section 6 concludes the paper.

2. Taking stock of the issues

Since strong uncertainty runs throughout the process of innovation (Dosi 1988, Verspagen 2004), complete contracts for innovation cooperation cannot be written and these arrangements are likely to generate knowledge spillovers (De Bondt 1996). Innovation cooperation is therefore the mechanism through which knowledge spills between various organizations in the economy. If any knowledge spillovers exist in reality, they are channelled through this mechanism. If partners from different countries are involved, furthermore, cooperation on innovation channels knowledge over national borders. Given the pivotal role of knowledge spillovers in generating economic growth (Romer 1990, Aghion and Howitt 1998), it is imperative to improve our understanding of factors that explain these arrangements.

Cooperation unlocks the internal constraints for innovation. Arrangements to cooperate on innovation facilitate access to external sources of knowledge, spread costs and risks among the partners, and allow firms to benefit from division of labour in the innovation process (Gulati 1998, Sachwald 1998, Miotti and Sachwald 2003). Strategic motives point to cooperation as the organizational answer to increasing complexity of research and rapid technology progress. By networking firms can pool complementary resources with other organizations and make use of resources owned by others. Although some of these external resources can be purchased when needed on markets for technology (Arora et al. 2001), others are embodied in the people and organizations, which make them hard to transfer through market transactions (Lundvall 1988, Maskell and Malmberg 1999).

Building on evolutionary grounds, the interactive nature of innovation process has been elaborated in the literature on national innovation systems (Lundvall 1992, Nelson 1993, Edquist 1997). From this perspective the ability of firms to capitalize on external knowledge embedded in social networks is crucial for successful innovation process. Localized nature of interactive learning has been further emphasized in the literature on regional innovation systems (Asheim and Gertler 2004), which highlights relationships among the internal organization of firms, their connections to one another and to the social structures and institutions of their particular localities. At the core of these systemic approaches to innovation is therefore the idea that behaviour of firms in the innovation process needs to be understood in the context of the local framework conditions.

So what should we expect to find with regards to spatial differences in the propensity of firms to cooperate? A romantic prediction derived from the systemic perspective is that denser networks of cooperation on innovation between firms and other organizations hallmark a superior innovation system (OECD 2001, European Commission 2009), because these are the virtuous systemic interactions that facilitate reciprocal access to advanced knowledge generated in different parts of the system. Nevertheless, there could be a twin side of cooperation in less advanced environments. Firms can also cooperate precisely because of limited internal capabilities to solve problems arising in the innovation process alone, even though more capable firms can do so without involving others into the process elsewhere. Naturally, this puts the question of internal capabilities of firms to the forefront of this debate. Does the relationship between capabilities and cooperativeness of firms differ across countries? Could it be that in less advanced countries firms in fact strive to cooperate because of limited internal innovation capabilities?

At the centre of interest in this study, yet often neglected in the existing literature, is furthermore the relationship between cooperation with local and foreign partners. Firms increasingly need to pool resources from different external sources to innovate ever more complex products (Miotti and Sachwald 2003). Some of them are close, whereas others can be found only in distant locations. Innovation might be therefore perhaps best viewed as a result of a combination of close and distant interactions (Bathelt et al. 2004). It is likely that firms favour to cooperate with partners in their proximity, if anything to avoid costs and obstacles of venturing far away. In other words, firms are likely to start searching for partners locally and extend the screening to more remote locations only if they cannot find relevant partners in not too distant place.

From this naturally follows that firms should choose domestic over foreign partners for cooperation if there are partners with the needed complementary resources in their vicinity. A lack of complementary resources locally, for example in countries significantly behind the technological frontier, on the other hand, should encourage firms to engage with foreign partners to overcome shortcomings in the local knowledge base. Firms might not be able to find relevant partners for cooperation in the same country for two primary reasons. First, there is not much to choose from because the national innovation system is underdeveloped, so that firms escape the local poverty by cooperating with foreigners. Second, there are not many relevant domestic partners because the country in small. Size of the country is likely to matter for the propensity to engage with foreign partners for natural reasons, because firms in larger countries are by principle less likely to interact (trade, invest or cooperate) across national borders, because there are simply more domestic organizations to do business with.

An intimately related issue is the effect of foreign ownership of firms, a major symptom of globalization that channels knowledge between countries (Blomström and Kokko 1998), on their propensity to cooperate on innovation. Multinational corporations are known to limit spillovers of their knowledge to non-affiliated firms in order to protect their ownership advantages (Dunning 1988, Caves 1996), which may circumvent cooperation of foreign affiliates with local firms, so that they often remain poorly embedded in the local innovation system, especially in countries behind the technology frontier (Lall 1980, Kokko et al. 1996, UNCTAD 2001). But at the same time foreign ownership may bring significant side effects that catalyze knowledge flows across borders. Although going abroad for cooperation may not be easy, since all kinds of cognitive, institutional and other barriers stand in the way, as already pointed above, foreign ownership provides organizational proximity to distant locations (Lundvall 1988) that may help firms to overcome them. Hence, foreign affiliates should have an inherent advantage to access foreign partners for cooperation through contacts of their parents other firms in the group abroad.

It is important to understand, however, that international business does not undermine the role of local innovation systems (Narula 2003). Quite the contrary is in fact the outcome of globalization of production (Maskell and Malmberg 1999, Rugman and D’Cruz 2003). Free access to international markets in capital goods and other inputs, including codified knowledge, that for a given price become available for everybody actually strengthens the role of idiosyncratic strategic capabilities. Even if firms invest and cooperate abroad to tap into foreign sources of tacit knowledge (Chesnais 1992, Cantwell 1995), these strategic capabilities of firms remain by their very nature embedded in – possibly multiple but still – local innovation systems (Pavitt and Patel 1999). And the deepening specialization of firms in these core competencies within the globally dispersed production networks even more reinforces the need to pool complementary resources among various partners for innovation.

3. Overview of the dataset

The empirical analysis is based on a large sample of firms from the Third and Fourth Community Innovation Surveys (CIS3 and CIS4 henceforth) provided by Eurostat, which asked firms about various aspects of their innovation activity from 1998 to 2000 and from 2002 to 2004 respectively (Eurostat 2007 and 2009). Firms from the following sixteen European countries, including nine new EU members, are in the datasets: Belgium, Bulgaria, Czech Republic, Estonia, Germany, Hungary, Greece, Italy, Latvia, Lithuania, Norway, Portugal, Slovakia, Slovenia, Spain and Romania.[1]

Following the Oslo Manual (OECD 1997 and 2005) a harmonized questionnaire and methodology was used to collect the data. However, there are some prevailing national differences with regards to design of the questionnaire, industry coverage, or imputation of the missing data, which had to be dealt with to derive fully harmonized cross-country evidence; details on how this has been done are available from the author upon request. Some of the variables containing sensitive financial information, such as the value of turnover, exports or the amount of innovation expenditure, were so-called micro-aggregated by averaging data for three similar firms, though the binary and Likert scale variables remained unchanged in these datasets. Since we do not need to use the micro-aggregated variables, with only one exception further explained below, results of this study refer to evidence directly at the firm level.

All firms have been asked to provide information about structural characteristics with regards to their size, affiliation to a group or distance of their market, but only those firms that claimed to innovate has been asked to provide further details on their innovation activity, including the questions on cooperation, R&D activity or sources of information. Since the cooperative behaviour concerns only those firms that attempted to innovate, and there is a lack of instrumental variables that could identify Heckman sample selection model, we restrict the sample to innovation active firms according to definition of the Oslo Manual; i.e. those that introduced a new product, a new process or reported not yet completed or abandoned innovation activities over the reference period. [2] It is therefore important to bear in mind that the evidence presented below refers only to the sub-sample of innovating firms and should be interpreted accordingly.

Our dependent variables are derived from the set of questions on whether the firm cooperated on any of its innovation activities with other organizations.[3] Firms were asked to indicate the

[1] For most countries the reference period was according to the recommendation, the exception being that the Czech Republic, Hungary, Latvia, Lithuania and Norway covered the period from 1999 to 2001, Romania covered the period from 2000 to 2002 and Bulgaria covered the period from 2001 to 2003 in CIS3; and the Czech Republic had a reference period from 2003 to 2005 in CIS4. Also data from Iceland is included in the CIS3 CD-ROM distributed by Eurostat, but this information could not be used in this analysis due to missing data for the key variables for about two-thirds of the sample.

[2] By focusing on the innovative active firms, the inferences presented below can be influenced by a sample selection bias, which arises when the dependent variable is observed only for a non-randomly restricted sample. To correct for the possible bias, we could use the so-called Heckman's procedure (Heckman 1976). But to properly identify the exclusion restriction we require a variable that is a relevant predictor of the propensity of firms to innovate but not of their propensity to cooperate. Unfortunately, there is no variable with these properties available in the data, so that the only way to identify the selection turned out to be the functional form, though this has been deemed as unsatisfactory.

[3] Innovation cooperation was exactly defined as active participation with other enterprises or non-commercial institutions on innovation activities in the harmonized CIS4 questionnaire and as active participation in joint

location and type of the partner, from which we derive a series of more detailed dummy variables. As far as the location is concerned, firms reported whether they cooperated with a partner in their home country or a partner located abroad with a distinction into several groups of foreign countries, which we condense into shortcuts “dom” for a domestic partner, “for” for a partner in at least one foreign country and in addition “tot” for a total combination of (domestic or foreign) partners that are used to delineate the respective form of cooperation in names of the variables. Seven types of the partner organisation are distinguished with the following shortcuts: GP (other enterprises within the respondent’s group of firms); SUP (suppliers of equipment, materials, components, or software; CUS (clients or customers); COM (competitors or other enterprises in the same sector); INS (consultants, commercial labs, or private R&D institutes); UNI (universities or other higher education institutions); and GMT (government or public research institutes).[4]

Since one of the key predictors, for more see below, is the information whether the firm is affiliated to a (domestic or foreign) enterprise group, in the first instance we distinguish between internal cooperation along the ownership lines with other firms affiliated to the group (GP) and external cooperation with partners that are outside of the group (SUP, CUS, COM, INS, UNI or GMT), which gives the shortcut EXT for the external partners taken together. Naturally, only firms that are affiliated to a group can report cooperation with other members of the group, in other words these variables are correlated by definition, so that the internal cooperation needs to be excluded from definition of the dependent variable if the information on whether the firm is a part of a group is used as a predictor in the econometric estimates below.

Table 1 outlines genesis of the dependent variables. COdomGP, COforGP and COtotGP refer to dummies with value 1 if the firm reported cooperation with an affiliated partner within the group and COdomEXT, COforEXT and COtotEXT are dummies with value 1 if the firm had at least one cooperation arrangement with an (non-affiliated) external partner, where “dom”, “for” and “tot” stand for domestic, foreign or total partners, respectively. EXT is further decomposed in a battery of variables for each of the six types of external partners. Finally, COtotALL is an overall dummy with value 1 if the firm answered positively at least once, i.e. the firm has at least one cooperation arrangement regardless of the location (tot) and type (ALL) of the partner. Obviously, this gives quite complex stratum of dependent variables, which requires using (bivariate or) multivariate econometric methods, as further shown below.

R&D and other innovation projects with other organisations in the CIS3 questionnaire. Pure contracting out of work with no active collaboration was emphasized to be not regarded as cooperation in both of them.

[4] CIS3, but not CIS4, included a further distinction between consultants on one hand and commercial laboratories/R&D enterprises on the other hand, which we combined into the single “INS” category in this paper in order to use the same classification of partners.

Table 1: Definition of the dummy dependent variables of innovation cooperation

Type / location of the partner	Domestic location		Foreign location		Total location	
Other enterprises within your enterprise group	COdomGP		COforGP		COtotGP	
Suppliers of equipment, materials, components, or software	COdomSUP		COforSUP		COtotSUP	
Clients or customers	COdomCUS		COforCUS		COtotCUS	
Competitors or other enterprises in your sector	COdomCOM	COdomEXT	COforCOM	COforEXT	COtotCOM	COtotEXT
Consultants, commercial labs, or private R&D institutes	COdomINS		COforINS		COtotINS	
Universities or other higher education institutions	COdomUNI		COforUNI		COtotUNI	
Government or public research institutes	COdomGMT		COforGMT		COtotGMT	
All types of partners	COdomALL		COforALL		COtotALL	

To learn more about what drives cooperation of firms with the foreign partners in particular, which is the focal point of this analysis, we further create a multinomial variable COmnlEXT for external cooperation with four mutually exclusive outcomes delineated as follows: 0 if the firm did not cooperate (COtotALL = 0), 1 if the firm cooperated with a domestic external partner only (COdomEXT = 1 and COforEXT = 0), 2 if the firm cooperated with a foreign partner only (COdomEXT = 0 and COforEXT = 1), and 3 if the firm cooperated with both domestic and foreign partners at the same time (COforEXT = 1 and COdomEXT = 1). The idea is to create a variable that allows us to zoom on those firms that cooperate exclusively with partners abroad on one hand or at home on the other hand, because as shall be shown below so many cooperating firms tend to engage with both of them, which makes their distinction somewhat futile in context of the bivariate model.

Besides a battery of industry and country dummies to control for the respective contextual effects, we take into account a number of firm-specific explanatory variables that include structural characteristics of firms given by their size, ownership structure and distance of their market and a set of variables that capture resources, capabilities and perceptions of firms with regards to the innovation process represented by their R&D activity, screening of external sources of knowledge, appropriability conditions of their knowledge base and how the firms perceive obstacles to innovation. All of these have been suggested as relevant explanatory factors of the cooperative behaviour of firms in the literature discussed above, most of them have been also already tested in the existing empirical studies on this topic, however it will be interesting to see whether their effects differ by the different kinds of cooperative arrangements and last but not least to compare these effects across the different national settings. Let us now provide more detailed definition of these firm-level predictors.

Scale advantages are essential to control for, because the cooperation variables refer to firms having at least one cooperation arrangement, so that larger firms are by principle more likely to report at least one positive answer. Nevertheless, size of the firm proved difficult to measure in this data, since the number of employees, which is the conventional measure of size in empirical studies like these, has been perceived as confidential information by Eurostat, and therefore not included in the datasets, not even in the micro-aggregated form. CIS4 data provides only classification of firms into three broad categories in terms of employment, from which we derive dummies for SMALL (0-49 employees), MEDIUM (50-249 employees) and LARGE (more than 250 employees) firms. Size turned out to be even more problematic to determine in the CIS3 dataset, which includes the same size classification in terms of employment, but more than two-thirds of the firms have been assigned to mixed classes of these three broad size categories, which makes this information useless in the econometric framework.[5] At least, however, this dataset includes the micro-aggregated value of turnover, which can be used to proxy for the size classes of firms, because the standard Eurostat's definition of small and medium size enterprises (SMEs) refers not only to a threshold on the base of employment but also in terms of turnover.[6] According to this definition, we therefore classify firms in the CIS3 dataset by the three size categories on the base of their annual turnover into SMALL (not exceeding EUR 7 million), MEDIUM

[5] Also in the CIS4 data from Italy these size categories were combined for certain observations, which must have been excluded from the analysis, but these accounted for less than 5% of the Italian sample, so that this should not have a large effect on the reported results.

[6] For more details see 96/280/EC: Commission Recommendation of 3 April 1996 concerning the definition of small and medium-sized enterprises. Note that we use the Commission Recommendation of 3 April 1996, which is no longer in force, rather than the more recent 2003/361/EC definition that is in force from 6 May 2003, because the value of turnover in the CIS3 dataset refers to the earlier period.

(exceeding EUR 7 but not exceeding 40 million) and LARGE (exceeding EUR 40 million).[7] Both in CIS3 and CIS4 these dummies refer to size of the firms at the beginning of the reference period. SMALL is used as the based category and is therefore excluded from the estimates.

Alternatively, we could simply use the natural logarithm of the micro-aggregated turnover, but then results of the size variables (and therefore also possibly of the other coefficients) may not be comparable between the estimates based on the CIS3 and CIS4 data, which has been deemed as a major disadvantage. Since size of the firms in terms of employment, it should be further noted, has been a major input into the micro-aggregating procedure of turnover, only data for firms in the same size categories should have been aggregated together, and therefore the size dummies derived in the CIS3 data should be actually very close to the firm-specific information. Furthermore, this classification produced within country size distributions of firms that are broadly comparable (if adjusted for non-response, etc.) to the structure of the same CIS3 samples by size based on employment available for download at the aggregated level from Eurostat on-line, which indicates that the size categories based on turnover used here should not suffer from a major bias.

Next, two predictors have been derived from the question whether the firm is a part of an enterprise group, which should provide the firm with extended reach both organizationally and geographically, and therefore boost its odds to find a relevant partner (even an external one) for cooperation. Affiliated firms were further asked about the country where the head office is located, which we use to derive two mutually exclusive variables for the group membership. FORGP, which is used as a proxy for foreign ownership, has value 1 if the firm is affiliated to a group with headquarters abroad. DOMGP has value 1 if the firm is affiliated to a group with headquarters in the same country. Unfortunately, the questionnaire does not allow us to identify whether the domestic-based group has operations in other countries, so that this dummy covers not only solely domestic groups, but also home-based multinational corporations. In any case, firms affiliated to a domestic group are likely to be much more rooted in the national environment than those with headquarters abroad with obvious implication for cooperation at home. All other firms are NOGP, which means non-affiliated to a group, and these are used as the base category.

EXP is a dummy for exporters, which represents market proximity to foreign locations. This variable is defined slightly different in the CIS3 and CIS4 datasets. CIS4 included a straightforward question on which geographic markets did the firm sell goods or services with a distinction between local, national, other EU and all other countries, so that EXP has value 1 in the firm reported to deliver to the foreign markets. CIS3 asked about geographic distance of the most significant market, so that in this sample the EXP dummy has value 1 if the firm's main market has been marked as international (and with a distance of more than 50 km). The main difference is that answers to these questions were mutually exclusive in CIS3, i.e. only one geographic market can be "the most significant", whereas firms were allowed to check several positive answers in CIS4, so that the variable is relatively more restrictive in the former. If the firm exported, but the foreign market did not happen to be the most significant market, the EXP variable has value 0 in CIS3, but value 1 in CIS4.

[7] Unlike employment, however, currency units need to be transformed into a common base for international comparison. Since the sample includes countries at largely different levels of development, and therefore with different ratios between the nominal exchange rate and purchasing power of the local currency, the turnover figures reported in nominal EUR in the dataset have been adjusted according to purchasing parity standards (PPS) before constructing dummies for the size categories.

Furthermore, firms were asked for details about their innovation activity, from which we develop four variables on their resources, capabilities and perceptions with regards to the innovation process. A traditional measure in this domain is whether the firm devotes resources to research and experimental development (R&D) activity that is routinely used in empirical studies to represent not only the ability of firms to generate new knowledge, but also their capacity to absorb relevant knowledge from outside (Cohen and Levinthal 1990), which should obviously boost their cooperativeness for both reasons. R&D dummy has value 1 if the firm engaged into this activity over the three-year reference period.[8]

Another relevant question refers to the openness of firms to sources of information from outside, which captures their absorptive capacity from a different angle (Veugelers and Cassiman 1999). Firms were asked to indicate importance of information for their innovation projects from a number of sources, including those that the question about cooperation refers to such as suppliers, customers, competitors, research institutes, universities, etc., but also from "other" external sources such as various professional events, journals and associations. To avoid overlap in definition between the dependent cooperation variables and the explanatory variable derived from this question, for instance by attempting to explain cooperation with a supplier by a variable reflecting importance of information from the same source, we do not take into account the first group of sources. INFO dummy has value 1 if the firm indicated either i) conferences, trade fairs, exhibitions; ii) scientific journals and trade/technical publications; or iii) professional and industry associations in CIS4; and i) professional conferences, meetings, journals; or ii) fairs and exhibitions in CIS3, as highly important sources of information for their innovation activity. The idea is that in these questions the firm declared general openness to external information, which should allow us to discriminate between inward and outward looking strategies. Screening of these information sources provides the firm with enhanced knowledge about the pool of potential partners for cooperation, in other words the "know-who" kind of knowledge in terms of Lundvall and Johnson (1994), which should make the firm relatively more likely to team up with others in the innovation process.

Appropriability conditions of the firms' knowledge base given by their ability to protect intellectual property rights by patents or other means has been also shown to be one of the key predictors of cooperation (Cassiman and Veugelers 2002). For this factor, the survey provides us with a set of binary answers on questions about making use of formal methods to protect technology developed by the firm. PROT is a dummy which takes value 1 if the firm applied for a patent, registered an industrial design, registered a trademark or claimed copyright. Being able to limit outgoing spillovers of knowledge by these formal means should boost the appetite of firms for opening gates for the external cooperation partners, and therefore increase the odds of a positive outcome on the dependent variables.

[8] In CIS3 this variable combines a question whether the firm engaged in R&D in the final year of the reference period and a separate question whether the firm engaged in R&D continuously or occasionally over the three year period, so that the R&D dummy variable has value 1 if the firm answered positively on the first and indicated to engage in R&D at least occasionally over the whole period in the second. Hence both in CIS3 and CIS4 the R&D dummy refers to the three-year period. However, in Estonian, Latvian and Lithuanian CIS3 sub-samples data on the second question turned out to be corrupted, because all firms had values indicating either occasional or permanent R&D, i.e. according to the data there should have been no firms without R&D over the three-years, which is not possible, hence for these sub-samples the R&D dummy refers only the first question on R&D in the last year, which includes a realistic amount of zeros.

Firms were further asked to assess the extent to which they struggled with various hampering factors in the innovation process. For the sake of comparability, we take into account only those kinds of obstacles with close counterparts in both CIS3 and CIS4, which therefore refer to financial, cost-driven and lack of internal capability hampering factors. OBS that stands for obstacles is a dummy with value 1 if the firm marked at least one of i) Lack of funds within the enterprise or group; ii) Lack of finance from sources outside the enterprise; iii) Innovation costs too high; iv) Lack of qualified personnel; v) Lack of information on technology; or vi) Lack of information on markets in CIS4; and i) Innovation costs too high; ii) Lack of appropriate sources of finance; iii) Lack of qualified personnel; iv) Lack of information on technology; or v) Lack of information on markets in CIS3, as highly important hampering factors. The rationale for this variable is to single out those firms that faced acute difficulties in their innovation project. It should be emphasized, however, that these answers represent more than anything else firm's perceptions about the obstacles, which may not be comparable in an objective sense, and should be interpreted accordingly (Mohnen and Röller 2005, Clausen 2008). Arguably, firms that perceive stronger internal difficulties should be more likely to search for external help, but on the other hand these obstacles might undermine the project to the extent that cooperation becomes unfeasible. It will be interesting to see which of these effects prevails.

Finally, industry dummies delineated by the IND shortcut are based on a classification that broadly follows alphabetical NACE, rev. 1.1 structure with 20 categories in CIS4 and 17 categories in CIS3 covering firms in both industry and market services.[9] Food and tobacco manufacturing (DA) is used as the base category in the estimates, because this industry is populated by relatively many firms in all countries and the overall cooperation propensity of firms in this industry is very close to the sample mean (which is relevant for interpretation of the logit multilevel estimates, as further explained below). Similarly, county dummies delineated by the NAT shortcut are derived from location of the firms within borders of the respective countries.

[9] More detailed industrial classification was not possible to use due to limitations of the datasets, which includes only relatively aggregated codes due to confidentially concerns by Eurostat. Definition of the industry dummies used in the analysis is available from the author upon request.

Table 2 provides descriptive overview of the micro data. After omitting observations with missing records, the sample includes information for 28,623 firms from CIS4 and 13,827 firms from CIS3. Almost a third of the innovating firms in the sample engaged in cooperation arrangements on innovation, excluding the affiliated partners from the definition or not, most of the cooperating firms had a domestic partner, but only about half of them ventured into cooperation with a partner abroad. Let us leave, however, more detailed analysis of descriptive evidence on the cooperation variables by location, type of the partner and country for the next section.

As far as the predictors are concerned, about a fifth of the firms are large, a third of them are medium size, from which follows that roughly half of the sample consists of small firms. Firms affiliated to a domestic group are much more frequent than those with headquarters abroad, though both of them are relatively well represented in the data, which is important for deriving reliable estimates of their effects. More than half of the innovating firms engaged in R&D activity, about a quarter of them maintained good overview of the potential external partners and a third of them managed to protect their knowledge base by formal methods. Almost every second firm in CIS4 and little bit less in CIS3 reported facing acute obstacles in their innovation activity. Arguably, more interesting than these descriptive numbers for the sake of this paper is the relationship of these variables to the propensity of firms to cooperate, which we shall not delve more into descriptively, and rather explore in more detail in the econometric framework below.

Overall, the descriptive statistics comes out very similar for the CIS4 and CIS3 datasets, which suggests that there has not been much change in the innovative behaviour of firms between the two periods, but also confirms that definition of the variables is highly harmonized, which is encouraging for comparison of the econometric results. The main difference is in the EXP variable, which should be expected, because this one has noticeably different definition, as explained above. Also it should be noted that the size distribution of firms appears fairly similar in both vintages of the survey, which confirms that definition of these variables based either on employment or turnover gives comparable numbers, at least as far as the aggregate descriptive statistics is concerned.

Since we are going to estimate multilevel models, we need data for specific country-level variables that capture national framework conditions relevant for explaining the propensity of firms to cooperate on innovation. To limit influence of shocks and measurement errors occurring in specific years, we use the macro indicators in the form of three-year averages over the reference period.[10] All of the indicators are used in logs, partly because of non-linearity is likely to be involved in these effects as commonly assumed in the literature, but also because outliers in some variables were detected, which has been solved by the logarithmic transformation. Since the CIS3 data covers a smaller sample with too few countries to reasonably estimate a multilevel model, we gather the macro variables for and estimate these models only on the CIS4 data. All of the macro variables have been obtained from Eurostat on-line, only except of the FDI data which has been derived from UNCTAD FDI Statistics on-line.

[10] Since the reference period differs in some countries, we kept this in mind when constructing the country-level variables, so that we computed averages over different three-year periods depending of the timing of the survey in the particular country.

Table 2: Descriptive overview of the micro data

	Mean	Std. Dev.	Min	Max	N
		CIS4:			
COtotALL	0.334	0.472	0	1	28,623
COtotEXT	0.312	0.464	0	1	28,623
COdomEXT	0.286	0.452	0	1	28,623
COforEXT	0.164	0.370	0	1	28,623
LARGE	0.184	0.387	0	1	28,623
MEDIUM	0.314	0.464	0	1	28,623
DOMGP	0.250	0.433	0	1	28,623
FORGP	0.155	0.362	0	1	28,623
EXP	0.588	0.492	0	1	28,623
R&D	0.583	0.493	0	1	28,623
INFO	0.214	0.410	0	1	28,623
PROT	0.326	0.469	0	1	28,623
OBS	0.452	0.498	0	1	28,623
		CIS3:			
COtotALL	0.327	0.469	0	1	13,827
COtotEXT	0.314	0.464	0	1	13,827
COdomEXT	0.280	0.449	0	1	13,827
COforEXT	0.174	0.379	0	1	13,827
LARGE	0.176	0.380	0	1	13,827
MEDIUM	0.278	0.448	0	1	13,827
DOMGP	0.215	0.411	0	1	13,827
FORGP	0.145	0.352	0	1	13,827
EXP	0.323	0.468	0	1	13,827
R&D	0.613	0.487	0	1	13,827
INFO	0.247	0.431	0	1	13,827
PROT	0.361	0.480	0	1	13,827
OBS	0.402	0.490	0	1	13,827

Source: Eurostat (2007 and 2009).

First, as a measure of the overall level of economic development, we use GDP per capita in PPS (Purchasing Power Standard), which refers to the GDPCAP variable in the following. It should be noted that there is a long list of variables that can be used to directly measure quality of the national research infrastructure, which have been readily employed for this purpose in the literature (Furman et al., 2002, Archibugi and Coco 2004, Fagerberg and Srholec 2008), such as for example R&D expenditure, R&D employment, the number of scientific articles, the number of EPO patents, etc. or a combination thereof, but all of these measures tend to be highly correlated to GDPCAP, which makes them impossible to use at the same time in econometric estimates for multicollinearity problems. Nevertheless, this is important to keep in mind, so that results of the GDPCAP variable are properly understood as representing a joint effect of a broad range of factors closely related to the level of development, including quality of the national research infrastructure. Second, as already discussed above, for natural reasons size of the country should be a relevant predictor of national differences in the propensity of firms to cooperate with foreign partners. To control for this effect, we use the total population of the country, which constitutes the POP variable.

Finally, globalization of the economy, or in other words the intensity of economic transactions across national borders, can play a role in the propensity of firm to venture for cooperation on innovation abroad. Among other things, the amount of foreign transactions reflects economic policies that can be directed at promoting (or restricting) the involvement of the country in the global economic system, which should have consequences for foreign cooperation on innovation too. Another possible influence can be seen in the realm of "demonstration" effects by firms going global through trade, investment and other means that may highlight avenues for foreign cooperation of other firms. Overall, the extent to which the economy is globalized represents general inward/outward orientation of the national system that besides economic factors can be given by history, geography or culture. A firm operating in an economy that is highly globalized for whatever reason should be expected to be in a relatively better position to engage in cooperation with foreign partners, as compared to a firm doing business in a relatively closed economic system.

Many different symptoms of globalization can be measured with harmonized data these days, from which we use three most widely used indicators as follows. IMP refers to a variable for import of goods and services. FDI represents the stock of inward foreign direct investment. And the LIC variable stands for outward licence payments (debit) for royalties and license fees derived from the balance of payments statistics. All three are expressed in % of GDP. Again, these indicators are too excessively correlated to each other to include them together in a regression estimate, so that we use this insight in a factor analysis to create of composite indicator. Since only a single principal factor with eigenvalue higher than 1 has been detected (the other two eigenvalues were -0.001 and -0.194 respectively), we have retained one factor that accounts for 49.3% of the total variability as follows: IMP (0.795), FDI (0.831) and LIC (0.395); factor loadings in brackets; N=15. Principal factors procedure has been used to find the solution and regression scoring has been used to generate the GLOBAL variable.[11]

Table 3 provides overview these macro variables. As already noted above, these are used in logs to limit the influence of outliers. Furthermore, the GDPCAP, POP and GLOBAL indicators have been standardized by deducting mean and dividing by standard deviation, so that these variables appear in the econometric estimates with mean of zero and standard deviation equal to one, which allows us to directly compare magnitude of their coefficients, because they are expressed in the same units of standard deviation after this transformation.

[11] GLOBAL takes into account only indicators of inward openness of the economy, because including the outward variants of IMP, FDI and LIC, which are readily available too, complicates interpretation of the score without adding much explanatory power for two major reasons. First, exports tend to be highly correlated in cross-country comparisons to imports, because strong forces balancing trade are in play. Of course, countries can run a trade deficit (or surplus), but levels of imports and exports relative to size of the country (in % of GDP) are extremely correlated. Hence, the intensity on imports by principle already carries out the information about the intensity on exports and vice-a-versa. But the main reason for not including none of the indicators of outward orientation into GLOBAL is that both the stock of outward foreign direct investment and incoming licence payments (credit) for royalties and license fees are highly correlated to GDP per capita, because these are mixed measures of outward openness but also of the technological level of the country. If we had included these into the factor analysis, the resulting GLOBAL score would be excessively correlated to GDPCAP, creating muticollineariy problems in the estimates.

Table 3: Descriptive overview of the macro data

	Macro variables (CIS4)			Number of observations	
	GDPCAP	POP	GLOBAL	CIS4	CIS3
Belgium	1.107	0.156	1.602	1,218	721
Bulgaria	-1.922	-0.075	0.285	2,216	848
Czech Republic	0.057	0.145	0.906	2,225	1,015
Estonia	-0.759	-1.540	1.171	903	688
Germany	0.980	1.888	-1.010	2,498	1,724
Greece	0.458	0.207	-1.480	383	..
Hungary	-0.419	0.139	1.231	934	243
Italy	0.849	1.585	-1.737	4,932	..
Latvia	-1.250	-1.088	-0.192	433	425
Lithuania	-1.029	-0.758	-0.137	549	622
Norway	1.687	-0.530	-0.850	1,326	1,512
Portugal	0.024	0.160	-0.155	2,055	790
Romania	..	..	..	..	1,793
Slovakia	-0.687	-0.390	0.733	677	403
Slovenia	0.245	-1.218	-0.115	653	..
Spain	0.660	1.318	-0.252	7,621	3,043
Northern Europe	1.258	0.505	-0.086	5,042	3,957
Southern Europe	0.498	0.818	-0.906	14,991	3,833
New EU members	-0.721	-0.598	0.485	8,590	6,037

Another figure presented in Table 3 that has not been mentioned so far is the number of observations per country. Overall, quality of the data has increased noticeably between CIS3 and CIS4, resulting in much higher representativeness of the samples in most countries in the latter, so that we put relatively more weight on evidence based on the later dataset. Since the number of innovating firms is relatively low in some of the national samples, which poses a serious problem for estimating the regression models outlined below separately for each of them, we report some of the estimates separately for regional groupings of firms from "Northern Europe" (Belgium, Germany and Norway), "Southern Europe" (Greece, Italy, Portugal and Spain) and the former centrally planned countries that joined the EU during the last two rounds of enlargement under the heading of "New EU members" (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Slovenia, Slovakia and Romania).[12] Such grouping splits the sample into different geographical areas but most importantly also allows us to detect broad differences along the overall level of economic development among other things. It is fully acknowledged that this is a relatively rough brush for detecting the national patterns, but these regional groups are only used to detect broad differences, which become examined in much more detail later.[13]

[12] Some of the national samples are relatively small in proportion to size of the country, such as from Hungary in CIS3 and Greece in CIS4, though we still keep them in the analysis for comparative purposes. Also one needs to keep in mind that these are the innovative firms only, so that in countries with relatively low innovation rates the total samples are much larger.

[13] Firms from Greece in CIS3 and Romania in CIS4 could not be used because there is no information provided on innovation cooperation by location and type of the partner in these waves of the survey. Data from Italy and Slovenia have not been included in the CIS3 CD-ROM distributed by Eurostat. Hence, the regional groupings have different composition in CIS4 and CIS3; with the main difference that "Southern Europe" covers Greece, Italy, Portugal and Spain in CIS4, but only Portugal and Spain in CIS3, which needs to be kept in mind, although this does not seem to undermine comparisons or the regional figures too much.

4. Exploring evidence on the cooperation variables

The aim of this section is to provide more detailed overview of the cooperation variables. Our focus here is on detecting main patterns in the data, on which we shall build in their closer examination as dependent variables in the following econometric estimates. First, we look at differences in the propensity to engage with external partners at home and abroad by countries and their groups. Second, we compare the propensity of firms to cooperate with different types of partners, and whether these tend to differ by the broad country groups. For this purpose, we run factor analysis on the battery of cooperation variables by the location and type of the partner to see how they relate to each other. In the last part of this section, finally, we look more closely at the perceived value of the various types of partners, which is particularly relevant for understanding the (internal) within group cooperation of affiliated firms.

Table 4 provides descriptive overview of the propensity of firms to external cooperation by location of the partner. About 31% of the firms engaged in innovation cooperation with at least one external partner (COtotEXT), of which roughly 15% cooperated only with a partner at home (COmnlEXT=1), about 3% cooperation exclusively with a partner abroad (COmnlEXT=2) and 14% cooperated with both domestic and foreign partners (COmnlEXT=3); with marginal differences between CIS4 and CIS3 reported separately in the columns. Arrangements on cooperation with partners at home are therefore much more prevalent than with those abroad. Although geography (or distance) clearly matters for the frequency of cooperation, so that the distinction between domestic and foreign partners seems to make sense, there is also a substantial overlap between them, because around four-fifths of firms that cooperate abroad also had a domestic partner.

A brief look at the comparison between the groupings of countries presented in the lower part of the table, which proves to be instructive for this purpose, reveals a significant regional division. Albeit there is not that much difference in the propensity of firms to cooperate exclusively with domestic partners by the regions, arrangements on innovation cooperation that involve a foreign partner are more than two times less prevalent in Southern Europe as compared to the group of advanced countries in Northern Europe but somewhat surprisingly also as compared to the new EU member countries. In other words, Southern Europe comes out with generally lower cooperation rates predominantly because firms operating in these countries tend to venture much less often into cooperation abroad, i.e. for a reason these firms are much more inward looking than elsewhere. At the group level, furthermore, firms in the new EU member countries report even slightly higher propensity to foreign cooperation, and consequently in total, as compared to those in Northern Europe.

Arguably, this is puzzling. Southern European countries have been described to have fragile national innovation systems for a long time; however, this has been understood to be even more the case of the "transition" innovation systems in the new EU member countries. Paasi (1998) found innovation systems in transitions countries relatively less efficient than in the market economies. Radosevic (2004) casts doubts about growth prospects of the Central and Eastern European countries, despite recently quite strong catching up, precisely because of fragmented innovation systems. Similarly, Högselius (2003) reported major gaps in systemic interactions among actors of the Estonian national innovation system, which he later held relevant for other countries in the region too. Even though the difference between the Northern and Southern Europe conforms to the traditional story in the national innovation

Table 4: Descriptive overview of COtotEXT and COmnlEXT by country

	CIS4				CIS3			
	COtotEXT	COmnlEXT=			COtotEXT	COmnlEXT=		
		1	2	3		1	2	3
Belgium	0.481	0.135	0.058	0.288	0.313	0.096	0.051	0.166
Bulgaria	0.211	0.077	0.038	0.096	0.272	0.101	0.055	0.116
Czech Republic	0.481	0.170	0.047	0.264	0.369	0.175	0.039	0.155
Estonia	0.359	0.107	0.053	0.198	0.366	0.119	0.045	0.202
Germany	0.286	0.159	0.012	0.115	0.282	0.177	0.010	0.095
Greece	0.256	0.107	0.039	0.110	..	..	..	..
Hungary	0.486	0.222	0.039	0.226	0.650	0.296	0.070	0.284
Italy	0.177	0.138	0.005	0.034	..	..	..	..
Latvia	0.432	0.141	0.039	0.252	0.506	0.136	0.080	0.289
Lithuania	0.596	0.211	0.071	0.313	0.458	0.151	0.088	0.219
Norway	0.452	0.155	0.027	0.270	0.415	0.211	0.034	0.170
Portugal	0.240	0.112	0.017	0.112	0.271	0.133	0.037	0.101
Romania	..	..	..	..	0.259	0.102	0.035	0.123
Slovakia	0.446	0.074	0.046	0.326	0.365	0.112	0.040	0.213
Slovenia	0.498	0.139	0.054	0.305	..	..	..	..
Spain	0.278	0.180	0.019	0.079	0.217	0.111	0.011	0.095
Northern Europe	0.377	0.152	0.027	0.198	0.338	0.175	0.027	0.137
Southern Europe	0.239	0.155	0.015	0.070	0.228	0.115	0.016	0.096
New EU members	0.402	0.136	0.046	0.220	0.352	0.132	0.050	0.170
All countries	0.312	0.149	0.026	0.137	0.313	0.139	0.034	0.140

Source: Eurostat (2007 and 2009).

system literature, namely that networks of cooperating firms tend to be much denser in advanced countries, evidence from the new EU members does not fit into this pattern, perhaps only with exception of the “southern” (and the least advanced) Romania and Bulgaria, which noticeably drags down the regional average. So why do firms in the new EU member countries appear to be among the most cooperative in Europe?

Admittedly, we should remind ourselves at this point that the dataset has been reduced to the innovating firms only, and that the share of innovation active firms is much lower in most of the new EU members than elsewhere. Only the minority of firms that innovate tend to be more cooperative, not the total population, which includes the majority of those, which do not even try to innovate. Yet this does not explain cooperativeness of the innovators. A tentative observation that we can perhaps offer at this point is that the reason why in CIS4 about 50% of firms reported to cooperate on innovation both in Belgium and the Czech Republic is likely to be quite different from each other. Even though the aggregate propensities to innovate might look similar, these numbers can capture quite different phenomena.

If evidence on innovation cooperation recorded in the CIS data captured predominantly the virtuous systemic interactions highlighted in the innovation systems literature, then we should clearly observe a downward trend of cooperativeness along the level of development, i.e. by far the highest propensities in Northern Europe, then lower rates in Southern Europe and then equal or even lower rates in the new EU members. But this is not right. At the first glance, what emerges from the data is a complex non-linear relationship, inverted U-shape or perhaps S-shape curve, between cooperativeness and the level of development. Could it be that the nature of innovation cooperation differs at the technology frontier as compared to less advanced countries? Could it be that the factors that motivate firm to cooperate at the technological frontier are quite different from those that start to make firms even more cooperative below a certain threshold of development?

Table 5 shows how often firms engage with the different types of partners. Because there are many categories of the cooperation variables, for the sake of space we do report each country separately, but only present figures for the regional groups. Four main observations should be highlighted. First, the most frequent partners are other firms, namely suppliers and customer, hence those linked to the respondent by up(down)ward linkages along the value chain. Universities, research institutes and consultants that constitute the national research infrastructure appear much less popular. Second, there seems to be a tendency for partners from the research infrastructure to be more often represented in the domestic cooperation arrangements, as compared to the foreign ones. In other words, distance matters much more for this type of partners. Third, firms in the new EU member countries tend to be relatively more involved with other firms, whereas firms in the North European countries tend to be noticeably more engaged as compared to the other regions in cooperation with universities. Finally, Southern Europe is lagging behind the other two regional groups in most of these figures, so that the overall propensity to cooperate is not driven by a certain type of partners only.

About two-thirds of the cooperating firms tend to have more than one type of partner, and about a quarter of them combine even four or more (out of the six) different types of partners, i.e. not taking into account the distinction between domestic and foreign partners here. If a firm ventures into cooperation, it typically gets engaged in networking relationships with

Table 5: Average propensity of firms to cooperate with external partners by region and the type of partner

	CIS4				CIS3			
	All countries	Northern Europe	Southern Europe	New EU members	All countries	Northern Europe	Southern Europe	New EU members
COtotSUP	0.212	0.242	0.137	0.325	0.198	0.189	0.116	0.256
COtotCUS	0.171	0.230	0.094	0.270	0.176	0.170	0.124	0.213
COtotCOM	0.111	0.120	0.071	0.175	0.107	0.091	0.073	0.139
COtotINS	0.134	0.165	0.098	0.179	0.165	0.166	0.125	0.194
COtotUNI	0.139	0.208	0.107	0.156	0.147	0.171	0.138	0.139
COtotGMT	0.075	0.157	0.037	0.093	0.109	0.120	0.126	0.094
COdomSUP	0.163	0.180	0.117	0.234	0.136	0.142	0.078	0.168
COdomCUS	0.134	0.180	0.080	0.201	0.132	0.138	0.083	0.159
COdomCOM	0.079	0.076	0.056	0.120	0.076	0.070	0.038	0.105
COdomINS	0.115	0.139	0.089	0.147	0.135	0.151	0.093	0.153
COdomUNI	0.130	0.191	0.102	0.143	0.134	0.161	0.126	0.125
COdomGMT	0.067	0.142	0.034	0.080	0.096	0.113	0.109	0.079
COforSUP	0.103	0.135	0.042	0.192	0.110	0.094	0.060	0.151
COforCUS	0.090	0.136	0.036	0.158	0.088	0.080	0.066	0.107
COforCOM	0.055	0.069	0.026	0.097	0.053	0.039	0.047	0.068
COforINS	0.044	0.066	0.022	0.067	0.067	0.052	0.062	0.081
COforUNI	0.032	0.069	0.020	0.030	0.037	0.045	0.037	0.034
COforGMT	0.017	0.040	0.008	0.020	0.029	0.027	0.039	0.024

Source: Eurostat (2007 and 2009).

several types of organizations simultaneously, not just one type at a time. And this leads us to the question whether some combinations tend to be more prevalent than others. To find out "unconditional" relations between them, we perform exploratory factor analysis on the cooperation variables by location and type of partners. Table 6 presents the results.[14] Only two relevant factors were detected explaining 73.4% and 72.4% of the total variance in CIS3 and CIS4, respectively.[15] So-called factor loadings, which are the correlation coefficients between the indicators (rows) and the retained principal factors (columns), are reported in the upper part of the table.

Table 6: Exploratory factor analysis on cooperation by the location and type of the partner

	CIS4		CIS3	
	Factor 1	Factor 2	Factor 1	Factor 2
COdomSUP	0.261	0.778	0.280	0.784
COdomCUS	0.377	0.789	0.326	0.807
COdomCOM	0.245	0.760	0.288	0.794
COdomINS	0.354	0.776	0.357	0.803
COdomUNI	0.504	0.666	0.484	0.705
COdomGMT	0.506	0.660	0.443	0.675
COforSUP	0.620	0.531	0.716	0.400
COforCUS	0.659	0.529	0.742	0.407
COforCOM	0.678	0.497	0.783	0.378
COforINS	0.794	0.364	0.844	0.321
COforUNI	0.874	0.258	0.812	0.312
COforGMT	0.875	0.227	0.839	0.248
1st eigenvalue	7.704		7.662	
2nd eigenvalue	0.987		1.142	
3rd eigenvalue	0.472		0.509	
4th eigenvalue	0.205		0.192	
5th eigenvalue	0.137		0.113	
6th eigenvalue	0.071		0.060	
% of total variance explained	72.4		73.4	
N	28,623		13,827	

Note: Principal factors extraction method; orthogonal varimax rotation.

[14] Since all of these variables are dummies, we use the so-called tetrachoric correlations in the factoring procedure (Kolenikov, Angeles 2004), which are more suitable for handling binary variables than the conventional correlation coefficients.

[15] According to the most widely used Kaiser criterion, only principal factors with eingenvalue higher than one should be retained, because these account for at least as much as the equivalent of one original variable, though the issue on how many factor to retain is not clearly identified in factors analysis. Another criterion, the so-called "scree" test, recommends plotting eigenvalues in a line plot and finding the place where the smooth decrease of the eigenvalues appears to level off, because to the right of this point, presumably, we find only "factorial scree". Since there are two factors with eigenvalue higher than one in CIS3 and the second eigenvalue in CIS4 is just around one, and the scree test suggest retaining two factors in each case, we decided to keep two factor scores in both. In other words, we do not keep only one in CIS4, which is strictly speaking suggested by the Kaiser criterion, so that the results can be easily compared between the two estimates.

The main outcome is that there is a strong common dimension in the data for firms to cooperate or not, regardless of the location or type of the partner organization. As far as there is a latent structure along these lines, if any at all, this refers to the distinction between the domestic and foreign cooperation partners, which tend to load together more highly on one of the principal factors than the other, although there is still quite strong overlap between them too. But differences between the types of partners within the realm of domestic on one hand and foreign cooperation on the other hand come out to be fairly negligible. In other words, this result suggests that for most firms the different types of partners, including the domestic and foreign ones, seem to be highly compatible with each other. Overall, this shows that there seems to be a strong "cooperate or not" behavioural pattern in the data.

Table 7: Average propensity of cooperating firms to combine different types of partners

		COtotGP	COtotSUP	COtotCUS	COtotCOM	COtotINS	COtotUNI	COtotGMT
CIS4	COtotGP	..	0.400	0.434	0.418	0.428	0.410	0.470
	COtotSUP	0.700	..	0.763	0.760	0.743	0.646	0.754
	COtotCUS	0.612	0.615	..	0.737	0.642	0.613	0.745
	COtotCOM	0.381	0.396	0.477	..	0.479	0.432	0.553
	COtotINS	0.472	0.469	0.502	0.579	..	0.566	0.691
	COtotUNI	0.471	0.424	0.499	0.544	0.590	..	0.815
	COtotGMT	0.291	0.267	0.327	0.376	0.388	0.439	..
	N	3,468	6,067	4,892	3,164	3,827	3,986	2,147
CIS3	COtotGP	..	0.425	0.428	0.457	0.443	0.431	0.452
	COtotSUP	0.661	..	0.720	0.774	0.719	0.641	0.667
	COtotCUS	0.592	0.640	..	0.780	0.636	0.625	0.659
	COtotCOM	0.385	0.419	0.475	..	0.458	0.434	0.471
	COtotINS	0.580	0.605	0.602	0.712	..	0.638	0.674
	COtotUNI	0.502	0.480	0.526	0.600	0.567	..	0.762
	COtotGMT	0.392	0.372	0.413	0.486	0.447	0.568	..
	N	1,757	2,738	2,434	1,481	2,304	2,048	1,526

Somewhat more descriptively the underlying combinations between the types of partners are presented in Table 7, where we focus on the cooperating firms only. Sub-samples of those firms cooperating with the respective type of partners delineate the columns, while the proportion of these engaging with the other types of partners is reported in the rows. In other words, this shows the frequency of different pairs of partners. For example, in the CIS4 dataset, 64.6% of firms that cooperated with a university (COtotUNI) combined this link with having at the same time a joined project with a non-affiliated supplier (COtotSUP). Some of the pairs are obviously less frequent than others, especially those with competitors or public research institutes, but from a bird's eye view, as already detected above, the different types of partners seem to be highly compatible with each other.[16]

[16] It should be noted, however, that these links do not necessarily refer to the same innovation project. In other words, these cooperation arrangements might have been forged separately in different projects within the firm. For example, consider a large firm with multiple divisions, of which one has cooperation with a university, while another one with a customer, so that the firm as a whole answers positively on both types of partners, but they might never meet in the same project together.

So far we have focused only on the external partners. If COdomGP and COforGP are added into the factor analysis presented above, however, they come out with very similar pattern of loadings as the external partners, i.e. high loadings with the other domestic, respectively foreign types of partners. COtotGP does not look much different from the other variables in the previous table either, which suggests that the variables for internal cooperation do not behave significantly different from the others. Yet, it is necessary to exclude these internal partners from definition of the dependent variable, if the predictors for being part of the group are included in the model, as already pointed above, which is why we examine them separately.

5. Econometric results

Following the issues outlined above, we estimate empirical models that predict cooperative behaviour of the innovative firms. Depending on the specification, the various CO indicators explored in the previous section represent the dependent variables, while the battery of firm-level predictors LARGE, MEDIUM, DOMGP, FORGP, EXP, R&D, INFO, PROT, OBS, the set of IND and NAT contextual dummies for sectoral and national differences and the country-level predictors GDPCAP, POP and GLOBAL introduced earlier in the paper appear on the right hand side. It should be stressed, moreover, that the estimates do not suffer from a serious problem of multicollinearity, because these explanatory variables are not excessively correlated to each other, which confirms that these predictors capture distinct phenomena; see Appendix 1 for correlation tables between the firm-level predictors.

Since the dependent variables refer to binary responses, we use maximum likelihood procedures to estimate various probit (and logit) models. Besides the basic univariate probit regression for a single binary response, multivariate probit estimates need to be used for categorical variables with correlated outcomes, and multinomial probit is required for discrete categorical dependent variables. To put national differences under closer scrutiny, we also estimate a multilevel (or hierarchical) specification with firms at level-1 and countries at level-2 of some of these models. Each of the regressions is delineated, explained and discussed, including the exact specification, before the results are presented. A majority of the estimates were performed in Stata 9.2, except of the multilevel models, for which we had to use specialized statistical software Hierarchical Linear and Non-linear Modeling (HLM) 6.06.

We divide this section into three parts, each focusing on a different set of dependent variables. Section 5.1 sets the stage for the debate by focusing on the general variable of external cooperation, which provides benchmark estimates of relationships between the variables, but also gives us the opportunity to explain the methodology of multilevel estimates on the base of this basic model. Section 5.2 dives more deeply in the distinction between cooperation with domestic and foreign external partners, which is the central issue of this paper. Finally, Section 5.3 looks more closely at cooperation by the types of external partners.

An important limitation of the analysis that needs to be emphasized is that not much could have been done about a potential endogeneity of the estimated coefficients mainly due to a lack of valid instruments in the dataset, which is admittedly a chronic problem for empirical research based on these surveys. Any interpretation in terms of causality between the explanatory and dependent variables should be therefore put forward with caution. Another related limitation given by the dataset in hand is the cross-sectional nature of the analysis, because the CIS3 and CIS4 datasets cannot be connected due to confidentiality of the respondents. It remains an important challenge for future research to address these caveats if better data become available, such as those being gathered for the purpose of follow up studies based on more detailed national evidence from the Czech Republic, Norway and the United Kingdom in the next phase of the GlobInn project.

5.1 Setting up the stage: Cooperate or not?

In this section, we develop models that predict the overall cooperativeness of firms on innovation. COtotEXT is the dependent variable. The aim is to indentify general patterns of the cooperative behaviour of firms, which provides benchmark results that should help us to understand what is specific about the more detailed cooperation variables examined in more detail below. First, we estimate a standard probit model that explains the propensity of firms to cooperate as follows:

$$\text{(1) } P(\text{COtotEXT}=1 \mid \beta) = \beta_0 + \beta_1\text{LARGE} + \beta_2\text{MEDIUM} + \beta_3\text{DOMGP} + \beta_4\text{FORGP} + \beta_5\text{EXP} + \beta_6\text{R\&D} + \beta_7\text{INFO} + \beta_8\text{PROT} + \beta_9\text{OBS} + \sum_{m=1}\beta_{10m}\,\text{IND} + \sum_{n=1}\beta_{11n}\,\text{NAT} + \varepsilon$$

where IND = 1 ... m is the set of industry dummies, NAT = 1 ... n is the set of country dummies and ε in the residual.

Tables 9.1 and 9.2 present the first set of results based on the CIS4 and CIS3 datasets, respectively. In the first column, we start by estimating the model on the full sample of firms from all countries together, and then in the other columns for comparative purposes we estimate the model separately for the broad regional groups. The aim is to explore heterogeneity of the estimated coefficients depending on the context that spans from the most advanced group of "Northern Europe", to "Southern Europe" and finally to the least advanced group of the "New EU members". Although the set of IND and NAT dummies is included in all of the estimates, we do not report their results in the table for the sake of brevity, because these variables are just used to control for the context-specific effects.

All of the predictors have highly significant and expected signs in the estimates based on the full sample, which confirms that the model is relevant for explaining the cooperative behaviour of firms. Size of the firm is important to control for due to scale advantages of various kinds involved in the decision of firms to venture into innovation cooperation, so that the effects of LARGE and MEDIUM dummy variables are in line with the expectations positive and with descending magnitude of the coefficient. Also R&D, INFO, PROT and OBS, which capture various resources, capabilities and perceptions of firms with regards to the innovation process, tend to be for obvious reasons already discussed above positively associated to cooperativeness of firms. R&D appears to be have the strongest effect given by magnitude of the estimated coefficient, which underlines the importance of internal technological capabilities of firms.

Affiliated firms, identified by the DOMGP and FORGP dummies, are more likely to engage in cooperation as compared to independent companies, even with the external (non-affiliated) partners, because the organizational proximity to parent companies and other firms in the group helps them to overcome cognitive, geographical or other barriers that might stand in the way, and therefore lubricates the propensity to find relevant partners for cooperation. It seems, furthermore, that this difference tends to increase with the decreasing development level of the country where the firms are located. Along the ownership divide by far the largest difference is observed in the new EU member countries, whereas the smallest gap came out in the North European region, where in most cases these variables even ceased to be statistically significant at the conventional levels.

Table 9.1: Probit results for COtotEXT (CIS4)

	All countries	Northern Europe	Southern Europe	New EU members
Constant	-1.084 (0.054)***	-1.251 (0.107)***	-1.384 (0.089)***	-1.428 (0.060)***
LARGE	0.372 (0.025)***	0.497 (0.058)***	0.348 (0.037)***	0.367 (0.045)***
MEDIUM	0.082 (0.020)***	0.119 (0.049)**	0.047 (0.028)*	0.145 (0.035)***
DOMGP	0.242 (0.022)***	0.061 (0.048)	0.244 (0.030)***	0.401 (0.045)***
FORGP	0.163 (0.025)***	0.056 (0.062)	0.123 (0.040)***	0.212 (0.040)***
EXP	0.119 (0.020)***	0.189 (0.048)***	0.100 (0.029)***	0.112 (0.035)***
R&D	0.535 (0.020)***	0.773 (0.054)***	0.529 (0.028)***	0.448 (0.034)***
INFO	0.208 (0.020)***	0.333 (0.049)***	0.166 (0.029)***	0.219 (0.035)***
PROT	0.292 (0.018)***	0.359 (0.043)***	0.275 (0.025)***	0.257 (0.034)***
OBS	0.116 (0.017)***	0.127 (0.042)***	0.147 (0.024)***	0.058 (0.030)**
Country dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Wald χ^2	4,085.85***	908.85***	1,424.78***	1,308.65***
Pseudo R^2	0.13	0.16	0.10	0.12
N	28,623	5,042	14,991	8,590

Note: Robust standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table 9.2: Probit results for COtotEXT (CIS3)

	All countries	Northern Europe	Southern Europe	New EU members
Constant	-1.808 (0.073)***	-1.776 (0.116)***	-1.799 (0.115)***	-1.392 (0.091)***
LARGE	0.528 (0.038)***	0.466 (0.064)***	0.850 (0.077)***	0.414 (0.062)***
MEDIUM	0.253 (0.030)***	0.217 (0.056)***	0.419 (0.064)***	0.222 (0.044)***
DOMGP	0.334 (0.033)***	0.135 (0.051)***	0.315 (0.062)***	0.491 (0.063)***
FORGP	0.211 (0.038)***	0.083 (0.068)	-0.175 (0.081)**	0.429 (0.057)***
EXP	0.170 (0.028)***	0.152 (0.050)***	0.281 (0.061)***	0.120 (0.043)***
R&D	0.436 (0.027)***	0.554 (0.056)***	0.562 (0.059)***	0.311 (0.038)***
INFO	0.178 (0.028)***	0.182 (0.053)***	0.180 (0.059)***	0.182 (0.040)***
PROT	0.236 (0.026)***	0.338 (0.047)***	0.164 (0.052)***	0.216 (0.039)***
OBS	0.186 (0.025)***	0.184 (0.046)***	0.141 (0.051)***	0.216 (0.038)***
Country dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Wald χ^2	1,953.39***	509.01***	598.55***	809.87***
Pseudo R^2	0.13	0.11	0.18	0.10
N	13,827	3,957	3,833	6,037

Note: Robust standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Another important finding that can be seen from the regional comparison is that the effects of the capability variables broadly follow an opposite tendency, especially for the R&D variable in the CIS4 sample, even though for the other coefficients the decreasing trend along the level of development does not follow such a straightforward trajectory. In other words, R&D seems to be much more intimately related to cooperation in more advanced environments, whereas organization proximity matters relatively more in less advanced countries. Generally speaking, these results show that there is a remarkable tendency for the estimated coefficients to differ across the development level of the country where the firms operate, which is arguably a substantial finding that deserves to be further examined in the following.

Nevertheless, there is more analytical, efficient and also elegant way to econometrically examine differences of the estimated coefficients across countries. So far one of a major assumptions of the econometric framework has been that the individual observations are independent from each other, or in other words, that these firms share the same homogenous environment. If a hierarchical structure of data exits, however, units belonging to the same group tend to have correlated residuals and the independence assumption is likely to be violated. By relaxing this assumption, so-called multilevel modeling provides statistically more efficient estimates, which are more "conservative", as Goldstein (2003) puts it, than those ignoring the hierarchical nature of data.[17]

A partial solution to account for the compositional effects, to which we have optioned for above, is to ignore the random variability associated with the higher-level factors and include into the estimate fixed effect dummies that correspond to the hierarchical structure of the data, such as the dummies for location of firms in different countries. Using dummies might be a useful quick-fix solution, if the purpose only is to control for the compositional effects, as we have done, but it is of a limited help if the prime interest of the study is to deepen understanding of the higher-level effects and their cross-level interactions themselves. Although we may detect rough patterns of the structure, a dummy is a "catch-all" variable for which we can only speculate what it really represents.

Apart from the statistical consequences, a proper recognition of data hierarchies allows us to examine new lines of questions. Using the example of firms in countries, the multilevel approach enables the researcher to properly explore the extent to which differences between countries are accountable for outcomes at the firm level. It is also possible to investigate the mechanics by which the national factors operate at the firm level and the extent to which these effects differ for different kinds of firms. For example, we may analyse whether differences in the development level of the country are more important for smaller than larger firms, for foreign affiliates more than domestic companies or for firms with advanced capabilities more than those without them. Such research questions can be straightforwardly examined by multilevel modeling, but can be neither easily nor properly examined by the standard methods.[18]

[17] It should be noted, however, that not only multilevel modeling relaxes the standard independence assumption on residual terms. Spatial autocorrelation techniques have been developed to produce valid statistical inferences if errors tend to be correlated regionally (Fotheringham et al. 2000). Also survey design and analytical tools recognize the need to take into account the hierarchical structure of the population (Skinner et al. 1989). Even though these procedures are deemed to be necessary to obtain efficient estimates, the higher-level effects typically do not merit a serious interest themselves. Only multilevel modeling allows us to look closely at the patterns and consequences of hierarchical structure of the phenomena in question.

[18] To the best of my knowledge, this is the first time multilevel modeling is used to study cooperation on innovation. So far multilevel modeling has been rarely used to study innovation; with the exception of recent papers by Srholec (2008, 2009b) that used this methodology to study national and regional effects on

A multilevel sometimes also called a hierarchical, random coefficient or mixed-effect model relates a dependent variable to predictor variables at more than one level (Luke 2004). Suppose a multilevel model has 2-level structure with firms at level-1 nested in countries at level-2. The aim is to explain firm's likelihood to cooperate on innovation by factors operating at the firm and country levels. COtotEXT is the dependent variable at the level-1, the vector of firm-level dummies for LARGE, MEDIUM, DOMGP, FORGP, EXP, R&D, INFO, PROT, OBS are the level-1 predictors, while the GDPCAP country-level variable is the level-2 predictor, which is included to test for differences of the coefficients along the overall level of development. Again, the set of industry dummies IND is included too, but country dummies NAT do not appear in this model, because the country-level differences are instead captured by the GDPCAP variable and the set of country-level residuals representing the unobserved heterogeneity across countries. A full specification of the logit multilevel model is the following:

(2) Level-1 model:

$$P\,(COtotEXT_{ij}=1 \mid \beta_j) = \eta_{ij}$$

$$\text{Log}\,[\eta_{ij} / (1 - \eta_{ij})] = \beta_{0j} + \beta_{1j}\,LARGE_{ij} + \beta_{2j}\,MEDIUM_{ij} + \beta_{3j}\,DOMGP_{ij} + \beta_{4j}\,FORGP_{ij}$$
$$+ \beta_{5j}\,EXP_{ij} + \beta_{6j}\,R\&D_{ij} + \beta_{7j}\,INFO_{ij} + \beta_{8j}\,PROT_{ij} + \beta_{9j}\,OBS_{ij} + \sum_{m=1} \beta_{10m}\,IND_i$$

Level-2 model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\,GDPCAP_j + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + \gamma_{11}\,GDPCAP_j + u_{1j}$$
$$\beta_{2j} = \gamma_{20} + \gamma_{21}\,GDPCAP_j + u_{2j}$$
$$\beta_{3j} = \gamma_{30} + \gamma_{31}\,GDPCAP_j + u_{3j}$$
$$\beta_{4j} = \gamma_{40} + \gamma_{41}\,GDPCAP_j + u_{4j}$$
$$\beta_{5j} = \gamma_{50} + \gamma_{51}\,GDPCAP_j + u_{5j}$$
$$\beta_{6j} = \gamma_{60} + \gamma_{61}\,GDPCAP_j + u_{6j}$$
$$\beta_{7j} = \gamma_{70} + \gamma_{71}\,GDPCAP_j + u_{7j}$$
$$\beta_{8j} = \gamma_{80} + \gamma_{81}\,GDPCAP_j + u_{8j}$$
$$\beta_{9j} = \gamma_{90} + \gamma_{91}\,GDPCAP_j + u_{9j}$$

where *i* denotes a firm, *j* denotes a country, γ_{00} ... γ_{91} are fixed effects and u_{0j} ... u_{9j} are random effects, or residuals in other words, of which γ_{00} is the estimated grand mean of the log-odds of firms to cooperate on innovation across countries, γ_{01} is the country effect on the intercept, u_{0j} tells us that the countries vary around that grand mean, γ_{10}, γ_{20}, γ_{30} ... γ_{90} are the estimated means of the firm-level slopes across countries, $\gamma_{11}, \gamma_{21}, \gamma_{31}$ … γ_{91} are the cross-level interactions between the firm- and country-level predictors and u_{1j}, u_{2j}, u_{3j} ... u_{9j} indicate that the firm-level slopes vary not only as a function of the predictors but also as a function of unobserved country effects; all of the random effects are assumed to be sampled from a normal distribution with expected zero mean and variance = σ^2_u.[19] Finally, β_{10m} indicate the

innovativeness of firms, and the paper by Goedhuys and Srholec (2009) that examined the extent to which various macro factors affect returns on technological capabilities of firms, though the cooperative behaviour of firms has not been considered in these papers.

[19] Note that there is not a term for the level-1 residual, because for a binary outcome the variance is completely determined by the population mean, and thus the residual is not a separate term to be estimated (Luke 2004, pg. 55)

estimated fixed effects of the industry dummies, which for the sake of tractability are not allowed to differ across countries.[20]

At level-1 the equation refers to firm-level relationships. If the level-2 equations were not specified, the level-1 relationships could have been estimated as a number of standard single-level models separately for each country. A multilevel model emerges, if we let the intercept β_{0j} and slopes β_{1j} ... β_{9j} to become random variables. Since the level-2 effects are identified by the subscript j, we have a hierarchical system of regression equations at different levels, where we allow each country to have a different average outcome and a different effect of the level-1 predictors on the outcome. Although a different firm-level model is delineated for each country, the level-2 equations tell us that the estimated intercept and slopes differ simultaneously across countries, in other words we assume the level-1 relationships to be influenced by the country effects.

Table 10 gives the results.[21] We estimate the model from bottom up. First, we consider a "basic" model with only the level-1 predictors and let the level-2 effects to be random variables. Second, we examine a so-called "intercept-as-outcome" model, which includes the level-2 predictor only for the intercept. And finally, in the last column, we report estimates of the full "slopes-as-outcomes" model outlined above, which relates the level-2 predictor to both the intercept and slopes. To improve interpretability of the results, we standardized the level-2 predictor GDPCAP by deducting mean and dividing by standard deviation, so that this variable enters the estimate with mean of zero and standard deviation equal to one too. Since the other variables are dummies, all of the predictors have a meaningful zero-point, which simplifies interpretation of the estimated parameters. Unfortunately, the CIS3 data includes only 13 countries, which proved unsatisfactory for this purpose, so that we estimate the multilevel model on the CIS4 sample only.

Results of the basic model are presented in the first column in Table 10. Even though there are no country-level predictors, the estimated random effects reported in units of standard deviation reveal to which extent the firm-level relationships differ by country. Note that a useful characteristic of the standard deviation is that for normally distributed data about 68% of the observations concentrate less than one standard deviation from the mean, and about 95% of the observations lie between two standard deviations below and above the mean. Overall, there is a lot of variability across countries. All of the firm-level fixed effects come out highly statistically significant and with the expected signs, but the estimated coefficients appear widely distributed around the mean highlighting their sensitivity to the national framework conditions.

For example, it can be easily calculated that the effect of FORGP is estimated in the range of [0.112, 0.426] for 68% of the countries and in the range of [-0.045, 0.583] for 95% of them, which indicates that there are countries where this coefficient is fairly close to zero, or could even turn out to be negative in extreme cases. In other words, the difference in

[20] β_{10m} can be allowed to differ by country by adding other m-1 equations to the country-level layer of the model, but this would substantially complicate the estimate. Obviously, there is a limit to how many country-level parameters can be estimated in a sample consisting of 15 countries only.

[21] As discussed by Goldstein (2003), the presence of more than one residual term makes the traditional estimation procedures inapplicable, so that specialized maximum likelihood procedures must be used to estimate these models, for which we have used those proposed by Raudenbush et al. (2004) and developed in specialized statistical software Hierarchical Linear and Non-linear Modeling (HLM) version 6.06.

Table 10: Multilevel results for COtotEXT (CIS4)

	(1)	(2)	(3)
<u>Fixed Effects:</u>			
For Intercept$_{ij}$ (β_{0j})			
Intercept$_{ij}$ (γ_{00})	-2.167 (0.217)***	-2.172 (0.179)***	-2.166 (0.184)***
GDPCAP$_j$ (γ_{01})	..	-0.428 (0.088)***	-0.492 (0.182)**
For LARGE$_{ij}$ slope (β_{1j})			
LARGE$_{ij}$ (γ_{10})	0.657 (0.085)***	0.662 (0.085)***	0.651 (0.076)***
GDPCAP$_j$ (γ_{11})	..	..	0.166 (0.081)*
For MEDIUM$_{ij}$ slope (β_{2j})			
MEDIUM$_{ij}$ (γ_{20})	0.213 (0.063)***	0.214 (0.061)***	0.211 (0.064)***
GDPCAP$_j$ (γ_{21})	..	..	0.007 (0.067)
For DOMGP$_{ij}$ slope (β_{3j})			
DOMGP$_{ij}$ (γ_{30})	0.495 (0.076)***	0.483 (0.075)***	0.516 (0.048)***
GDPCAP$_j$ (γ_{31})	..	..	-0.246 (0.052)***
For FORGP$_{ij}$ slope (β_{4j})			
FORGP$_{ij}$ (γ_{40})	0.269 (0.060)***	0.261 (0.060)***	0.270 (0.055)***
GDPCAP$_j$ (γ_{41})	..	..	-0.104 (0.059)*
For EXP$_{ij}$ slope (β_{5j})			
EXP$_{ij}$ (γ_{50})	0.223 (0.067)***	0.221 (0.066)***	0.225 (0.066)***
GDPCAP$_j$ (γ_{51})	..	..	0.022 (0.067)
For R&D$_{ij}$ slope (β_{6j})			
R&D$_{ij}$ (γ_{60})	0.886 (0.090)***	0.898 (0.089)***	0.889 (0.067)***
GDPCAP$_j$ (γ_{61})	..	..	0.231 (0.071)***
For PROT$_{ij}$ slope (β_{7j})			
PROT$_{ij}$ (γ_{70})	0.451 (0.053)***	0.463 (0.051)***	0.448 (0.049)***
GDPCAP$_j$ (γ_{71})	..	..	0.118 (0.051)**
For INFO$_{ij}$ slope (β_{8j})			
INFO$_{ij}$ (γ_{80})	0.386 (0.068)***	0.382 (0.067)***	0.384 (0.070)***
GDPCAP$_j$ (γ_{81})	..	..	0.017 (0.073)
For OBS$_{ij}$ slope (β_{9j})			
OBS$_{ij}$ (γ_{90})	0.156 (0.038)***	0.164 (0.038)***	0.157 (0.034)***
GDPCAP$_j$ (γ_{91})	..	..	0.081 (0.036)**
Industry dummies (β_{10m})	Yes	Yes	Yes
<u>Random effects:</u>			
Intercept$_{ij}$ (u_{0j})	0.797	0.640	0.660
LARGE$_{ij}$ slope (u_{1j})	0.269	0.273	0.230
MEDIUM$_{ij}$ slope (u_{2j})	0.198	0.193	0.203
DOMGP$_{ij}$ slope (u_{3j})	0.245	0.245	0.074
FORGP$_{ij}$ slope (u_{4j})	0.157	0.155	0.121
EXP$_{ij}$ slope (u_{5j})	0.208	0.205	0.207
R&D$_{ij}$ slope (u_{6j})	0.314	0.309	0.207
PROT$_{ij}$ slope (u_{7j})	0.158	0.145	0.131
INFO$_{ij}$ slope (u_{8j})	0.213	0.208	0.222
OBS$_{ij}$ slope (u_{9j})	0.093	0.089	0.053
Index of dispersion	1.000	1.000	1.001
Level-1 observations	28,623	28,623	28,623
Level-2 groups	15	15	15

Note: Non-linear unit-specific model with the logit link function; restricted maximum likelihood (PQL) estimate; coefficients and standard errors in brackets reported for the fixed effects; standard deviations reported for the random effects; *, **, *** denote significance at the 10, 5 and 1 percent levels cooperativeness on innovation between foreign affiliates and non-affiliated domestic firms largely depends on the national framework conditions, in which the firms operate. A closer look at distribution of the R&D coefficient reveals that this effect is estimated to be in the range of [0.572, 1.200] for 68% of the countries and in the range of [0.258, 1.514] for 95% of them, so that is some countries cooperation of firms on innovation seems to be intimately related to their R&D capabilities, while in a different national environment this link can be quite weak. Similar conclusions can be drawn for most of the other firm-level effects.[22]

Since non-zero random effects indicate un-modeled variability across countries, we shall attempt to reduce these residuals by including the level-2 predictor. Next, we therefore estimate the intercept-as-outcome model, which incorporates the GDPCAP variable into the model as a predictor of the level-1 intercept, but let the level-1 effects remain "unconditional" at the country level. As has been shown in the descriptive statistics above, there seems to be a tendency for the cooperativeness of firms to be inversely related in a non-linear fashion to the development level of the country, but we could have not really derived too much from this observation, because other relevant factors have not been controlled for. Nevertheless, in this estimate we do just that.

As can be seen in the second column in Table 10, this preliminary observation is firmly supported by the econometric results. GDPCAP comes out with highly statistically significant and negative effect on the intercept, in other words on the estimated mean of firms to cooperate on innovation, even after properly controlling for the relevant firm-level effects and allowing for the random country differences in a multilevel framework. Just to reiterate this major finding, these figures econometrically confirm that firms in relatively less develop countries are more likely to cooperate on innovation. Arguably, this is a fairly surprising conclusion, as according to the national innovation systems literature there should be denser networks of collaborating firms in more advanced countries, so that we should find exactly the opposite tendency.

Nevertheless, one possible explanation why the general effect of GDPCAP on the intercept came out significant could be that we did not control for the cross-level interaction terms. In other words, the effect of GDPCAP could primarily depend on characteristics of the firms themselves. If we account for this possibility, there may not be a central tendency detected along these lines anymore. To test for this hypothesis, we allow the GDPCAP variable to influence also slopes of the level-1 predictors in the full "slopes-as-outcomes" model, where we examine not only whether this variable directly explains the intercept, but also whether the development level of the country exerts an indirect effect by mediating the firm-level relationships. Given the large random differences in effects of the firm-level predictors across countries detected above, the idea is to test to which extent the GDPCAP variable accounts for these differences.

Table 10 gives results of the full model in the last column. Several statistically significant cross-level interactions have been detected, of which two main observations clearly stand out. First, there is the negative and highly significant interaction between the GDPCAP country variable and the DOMGP variable for domestically affiliated firms. To a lesser extent this is the case also for the interaction between GDPCAP and FORGP, although this effect is much less significant. Since the sign of these interactions is negative, this result suggests that

[22] Note that the predicted log-odds can be converted to an odds by $\exp(\eta_{ij})$ and to the predicted probability φ_{ij} by $\exp\{\eta_{ij}\}/(1+\exp\{\eta_{ij}\})$.

organizational proximity to other firms tends to be much more intimately related to cooperation for firms operating in less advanced countries. Second, there are the positive and statistically significant interaction terms between GDPCAP of the country and the R&D, PROT and OBS firm-level dummies, so that the positive effect of these resources, capabilities and perceptions increases with development level of the country.[23] In other words, organization proximity drives cooperativeness of firms in less advanced countries, while the latter capability factors matter much more in advanced economies.

Arguably, internal resources, capabilities and perceptions of firms, matter less for cooperation in the context of less advanced countries, because the process of innovation itself, to which these cooperation arrangements refer to, tends to be more focused on imitation, given by only new to the firm product and processes, rather than on innovation in a strict sense, as novelty for the market or even the whole world. Naturally, this "cooperation on imitation" with other organizations is more geared towards the absorption of existing knowledge, aimed at learning from others, and therefore relatively less intensive on own unique resources of firms. Yet a flipside interpretation of this tendency could be that firms in less advanced countries cooperate more often with other organizations to actually make up for limited investment in their internal innovation capabilities. For example, this could be a situation when firms cooperate with a university, because they cannot afford (or are not willing) to maintain a regular R&D department by themselves. Arguably, this interpretation puts these arrangements into a substantially different light, as further elaborated below.

Furthermore, all of the less advanced countries included in this study, it should be noticed, are former centrally planned economies, hence the result that affiliated firms, particularly those part of a domestic group, tend to be more cooperative in this context points to a possible "transition" element. Could it be that this past experience is still imprinted in how these firms innovate? Could it be that their cooperation routines with other organizations developed during the long period of central planning have survived the transition process? Could it be that the grouped firms in these countries, possibly remnants of the old conglomerates, innovate relatively more collectively for historical reasons? One should bear in mind that these surveys refer to periods at the turn of the century and early into this decade, which was still only about ten to fifteen years since the regime change in these countries. Admittedly, however, we do not have a clear measure of this effect, so that this "transition" interpretation of the results requires a relatively long stretch of imagination, and more research is clearly needed to establish whether there is the case or not.

After taking on board the cross-level interactions, statistical significance of the GDPCAP effect on the intercept has decreased from 1% to 5%, while the magnitude has slightly increased, which confirms that the interaction terms are relevant to control for in order to properly isolate the general tendency along these lines, but at the same time that the pattern of increasing cooperativeness of firms with decreasing development level of the country remains relatively strong. So how could this be? First, the historical reasons related to central planning just discussed above may play a role in this direct effect too, if firms in the less advanced new EU member countries generally inherited relatively more collectivistic approach to innovation from the past. Second, this points to the fact that this result can be driven by composition of

[23] Arguably, one would expect that firms become relatively more cooperative because of the obstacles in the context of less developed countries, hence the interaction term between GDPCAP and OBS variables should be negative, but this expectation is clearly not supported by the data. All of the cross-level interactions with this variable, however, came out insignificant in the multinomial multilevel estimate below, so that this effect is not robust to specification of the model, and we are therefore not discussing it in more detail here.

the sample, because more than half of countries in this data are from Central and Eastern Europe, so that this could be a regional, not a global, trend. It well might be that beyond some threshold of GDPCAP the relationship to cooperativeness of firms disappears or even reverses into negative, but we just do not observe this here. Nevertheless, given these results, we can say with some confidence that this pattern is real in this selection of countries.

Furthermore, these results may point to a major limitation of the cooperation dependent variable themselves. As already lamented by Veugelers and Cassiman (2004), this data reveal only whether a firm cooperated or not, but there is no information in the survey about the intensity, efficiency and results of this interaction. It well might be that the finding that the cooperative projects are more demanding on internal capabilities of firms in more advanced countries points to the fact that these projects tend to be more significant, intensive, and possibly productive, as compared to those reported in the context of less advanced countries. Admittedly, the total COtotEXT dependent variable puts all kinds of cooperation projects into one basket, which might not be very helpful for disentangling nature of these effects. Even though we do not have detailed information about characteristics of the projects like those mentioned above, we actually know much more even from the existing data than what has been used so far. Could it be that these results obscure the difference between cooperation with domestic and foreign partners or with the various types of partners?

Before turning the attention to the more detailed definitions of the dependent variables in the following sections, however, let us conclude this part of the paper by inspecting results of the random effects. After the GDPCAP variable has been included, standard deviation of the random effect for the intercept has slightly decreased, which confirms that a fraction of the unexplained variance across countries got accounted for by the overall level of development, but also that a lot remained unexplained by this single variable alone. Some of the cross-level interactions significantly improved the explanatory power of the model too; in particular the residuals of DOMGP and to a lesser extent of R&D have been reduced substantially. Overall, this suggests that we have explained some part of the un-modeled variability across countries by the GDPCAP variable, but a lot still remains to be unaccounted for. Nevertheless, we are not going to further extend the multilevel model at this point, but leave this exercise to the next section, where the other country-level variables taken into account in this paper make much more sense to be included into the model.

Another diagnostic measure of multilevel models that has not been discussed yet is the so-called index of dispersion. Although logit multilevel models do not have the level-1 error term, as already noted above, we can calculate a level-1 error variance scaling factor, the so-called "index of dispersion", which measures the extent to which the observed errors follow the theoretical binomial error distribution and therefore provides diagnostics of the non-linear specification (Luke 2004, pg. 57). Index of dispersion equal to 1 indicates perfect fit between the observed errors and the theoretical assumptions. A significant over- or under-dispersion indicates model misspecification, the presence of outliers or the exclusion of an important level in the model. Less than 5% dispersion is usually seen as satisfactory. The index of dispersion is equal or very close to unity, which confirms that from a technical point of view these estimates do not suffer from a major problem.

5.2 Cooperation at home and abroad: How are they related?

So far we have not considered the difference between domestic and foreign cooperation, which is the main purpose of this section. COdomEXT for cooperation with a domestic partner and COforEXT for cooperation with a foreign partner are the dependent variables. To examine in a more detail those firms that cooperate exclusively with domestic or foreign partners, we also use the COmnlEXT multinomial variable with four discrete outcomes that have been derived from the previous two variables. Since we have more than one possible outcome, the conventional univariate probit model is not satisfactory for this purpose. COdomEXT and COforEXT require a bivariate probit model, while COmnlEXT needs to be investigated in a multinomial probit framework. Finally, in the last part of this section we also experiment with a multilevel multinomial logit model with COmnlEXT as the dependent variable.

The bivariate probit model is a straightforward extension of the univariate probit model presented above for the purpose of estimating a model with two correlated binary outcomes jointly. If we calibrated two separate univariate models for each of COdomEXT and COforEXT, we would ignore the possibility that these decisions of firms might be correlated with each other. To allow for this overlap, we delineate a model with two equations relating both COdomEXT and COforEXT to the predictors as follows:

$$(3)\quad \begin{cases} P\,(\text{COdomEXT}=1 \mid \beta_{(1)}) = \beta_{0(1)} + \beta_{1(1)}\text{LARGE} + \beta_{2(1)}\text{MEDIUM} + \beta_{3(1)}\text{DOMGP} + \\ \beta_{4(1)}\text{FORGP} + \beta_{5(1)}\text{EXP} + \beta_{6(1)}\text{R\&D} + \beta_{7(1)}\text{INFO} + \beta_{8(1)}\text{PROT} + \beta_{9(1)}\text{OBS} \\ + \sum_{m=1}\beta_{10m(1)}\,\text{IND} + \sum_{n=1}\beta_{11n(1)}\,\text{NAT} + \varepsilon_{(1)} \\ \\ P\,(\text{COforEXT}=1 \mid \beta_{(2)}) = \beta_{0(2)} + \beta_{1(2)}\,\text{LARGE} + \beta_{2(2)}\,\text{MEDIUM} + \beta_{3(2)}\,\text{DOMGP} + \beta_{4(2)} \\ \text{FORGP} + \beta_{5(2)}\,\text{EXP} + \beta_{6(2)}\,\text{R\&D} + \beta_{7(2)}\,\text{INFO} + \beta_{8(2)}\,\text{PROT} + \beta_{9(2)}\,\text{OBS} \\ + \sum_{m=1}\beta_{10m(2)}\,\text{IND} + \sum_{n=1}\beta_{11n(2)}\,\text{NAT} + \varepsilon_{(2)} \end{cases}$$

where $\varepsilon_{(1)}$ and $\varepsilon_{(2)}$ are residuals sampled from the bivariate normal distribution that are assumed to be correlated with each other. In other words, this implies that the covariance of $[\varepsilon_{(1)}, \varepsilon_{(2)}]$ equals a constant ρ, rather than zero as is assumed in the univariate probit model, which indicates that the propensity of a firm to cooperate with domestic partners is allowed to be related to the propensity to cooperate abroad. As a consequence, a statistical test for $\rho = 0$ can be estimated that examines the interdependence of the two types of cooperation. If the correlation is positive, a propensity for a positive outcome on the former simultaneously advances with the latter, perhaps because they are complementary. But the correlation may be negative if trade-offs are involved, such as if firms tend to redirect cooperation from a domestic partner to a foreign one or vice-a-versa.

Apart of this relationship between the dependent variables, at the centre of our interest is the estimated effect of the FORGP dummy for foreign affiliates. As the explanatory variable of COdomEXT, this variable captures embeddedness of foreign affiliates in the host economy. Since the impact of foreign ownership on domestic cooperation is likely to be a mixture of positive and negative effects conditional on innovation strategy of the multinational company and attractiveness of the local milieu for cooperation, our expectation for the sign of this coefficient is ambiguous. As argued above, however, foreign affiliates should have a superior access to (even non-affiliated) partners for cooperation abroad through organizational proximity to their foreign parent and other firms in the group, so that we expect a strongly positive effect of FORGP on the COforEXT dependent variable.

Similarly information that comes along with sales to the foreign market captured by the EXP dummy, in other words market proximity abroad, should at least partly help to overcome the disadvantages given by geographical distance of partners for COforEXT, and therefore the exporters are expected to be in a better position to engage in cooperation arrangements with foreign partners. Again, the link between EXP and COdomEXT is somewhat less transparent, because this relationship should be positive if the arguably more competitive environment in foreign markets urges firms to intensify cooperation with relevant partners in the local milieu, but the export orientation may also have the opposite effect if exporters are prone to choose foreign over domestic partners for cooperation.

Table 11 presents results of the bivariate probit model based on the CIS4 sample in the left part and on the CIS3 sample in the right part of the table, respectively. Let us first compare the estimated effects for COdomEXT and COforEXT. As hypothesized above, the main difference is in the coefficients of FORGP and EXP, which come out to be highly significant explanatory factors of both, but in terms of the magnitude their effect on domestic cooperation is marginal, while their effect on the propensity of firms to engage in cooperation with foreign partners is quite potent. Hence, the results strongly support the thesis that foreign affiliates capitalize on connections of their parent company and other firms in the group abroad. But the market proximity abroad comes out to be equally important to take into account in order to understand the difference. All of the other predictors have remarkably similar effects on both of the dependent variables.

Some studies using samples of firms from innovation surveys in individual countries, such as the analysis of Belgian data by Veugelers and Cassiman (2004) and the Czech data by Knell and Srholec (2004), even found that foreign ownership tends to be negatively associated with domestic cooperation. However, our results do not support this finding. Although magnitude of the coefficient is very small, we side with the result based on the same CIS3 dataset reported by Srholec (2009a) that, if anything, foreign ownership tends to be positively associated with domestic cooperation.[24] As far as the cooperation arrangements (with non-affiliated) foreign partners are concerned, we are in agreement with both Knell and Srholec (2004) and Srholec (2009a), who found strongly positive impact of foreign ownership in the Czech context and in the CIS3 micro-aggregated dataset from Eurostat, respectively; note that Veugelers and Cassiman (2004) did not test for this relationship.

[24] It should be noted, however, that the aforementioned studies used a somewhat different framework and the effects of foreign ownership on domestic cooperation turned out to be sensitive to specification of the model, so that these results might not be entirely comparable.

Table 11: Bivariate probit results for COdomEXT and COforEXT

	CIS4		CIS3	
	COdomEXT	COforEXT	COdomEXT	COforEXT
Constant	-1.176 (0.054)***	-1.899 (0.062)***	-1.862 (0.074)***	-2.324 (0.084)***
LARGE	0.360 (0.025)***	0.442 (0.029)***	0.532 (0.038)***	0.577 (0.042)***
MEDIUM	0.066 (0.020)***	0.111 (0.024)***	0.251 (0.030)***	0.264 (0.035)***
DOMGP	0.209 (0.022)***	0.295 (0.026)***	0.313 (0.033)***	0.336 (0.037)***
FORGP	0.081 (0.026)***	0.346 (0.028)***	0.108 (0.038)***	0.370 (0.041)***
EXP	0.085 (0.020)***	0.407 (0.025)***	0.068 (0.029)**	0.391 (0.032)***
R&D	0.534 (0.020)***	0.532 (0.025)***	0.456 (0.027)***	0.354 (0.032)***
INFO	0.207 (0.020)***	0.275 (0.023)***	0.199 (0.028)***	0.222 (0.031)***
PROT	0.290 (0.018)***	0.325 (0.021)***	0.231 (0.026)***	0.294 (0.029)***
OBS	0.117 (0.017)***	0.095 (0.020)***	0.176 (0.025)***	0.187 (0.029)***
Country dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
ρ	0.782 (0.007)***		0.776 (0.009)***	
Wald χ^2	6,071.25***		2,705.95***	
N	28,623		13,827	

Note: Robust standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Finally, the residuals are highly positively correlated, which strongly supports the notion of interdependence between the decisions of firms to cooperate at home and abroad. Strictly speaking, this may not necessarily be due to complementary nature of these cooperation strategies, but due to omitted factors affecting both types of cooperation, though we side with the former interpretation, because so many relevant factors have been accounted for in the model, and the relationship appears quite strong. Firms do not choose between a domestic or foreign partner, they most often combine both. Arguably, this is a relevant policy finding, because this result shows that fears of hollowing out of the local innovation systems by increasingly globalized interactions of firms in the innovation process do not seem to be justified by the results.

Even though COdomEXT and COforEXT appear to be compatible in many ways, there are firms with exclusively domestic or foreign partners, which might be obscured by the general correlation between them, but which are interesting for us in their own right, exactly because they deviate from the typical behaviour. To understand better these cases, we estimate the multinomial probit model with four discrete categories of the COmnlEXT variable, as already defined above, given by 0 for firms that did not cooperate, 1 for those that cooperated with a domestic external partner only, 2 for those that cooperated with a foreign partner only, and 3 for firms with both domestic and foreign partners simultaneously. Naturally, the first outcome is the base category, so that the estimated regression equation is delineated as follows:

$$(4)\quad \left\{ \begin{array}{l} P\,[\text{COmnlEXT}=1 \,/\, \text{COmnlEXT}=0) \mid \beta_{(1)}] = \beta_{0(1)} + \beta_{1(1)}\text{LARGE} + \beta_{2(1)}\text{MEDIUM} + \\ \beta_{3(1)}\text{DOMGP} + \beta_{4(1)}\text{FORGP} + \beta_{5(1)}\text{EXP} + \beta_{6(1)}\text{R\&D} + \beta_{7(1)}\text{INFO} + \beta_{8(1)}\text{PROT} \\ + \beta_{9(1)}\text{OBS} + \sum_{m=1}\beta_{10m(1)}\,\text{IND} + \sum_{n=1}\beta_{11n(1)}\,\text{NAT} + \varepsilon_{(1)} \\ P\,[\text{COmnlEXT}=2 \,/\, \text{COmnlEXT}=0) \mid \beta_{(2)}] = \beta_{0(2)} + \beta_{1(2)}\,\text{LARGE} + \beta_{2(2)}\,\text{MEDIUM} + \\ \beta_{3(2)}\,\text{DOMGP} + \beta_{4(2)}\,\text{FORGP} + \beta_{5(2)}\,\text{EXP} + \beta_{6(2)}\,\text{R\&D} + \beta_{7(2)}\,\text{INFO} + \beta_{8(2)}\,\text{PROT} \\ + \beta_{9(2)}\,\text{OBS} + \sum_{m=1}\beta_{10m(2)}\,\text{IND} + \sum_{n=1}\beta_{11n(2)}\,\text{NAT} + \varepsilon_{(2)} \\ P\,[\text{COmnlEXT}=3 \,/\, \text{COmnlEXT}=0) \mid \beta_{(3)}] = \beta_{0(3)} + \beta_{1(3)}\,\text{LARGE} + \beta_{2(3)}\,\text{MEDIUM} + \\ \beta_{3(3)}\,\text{DOMGP} + \beta_{4(3)}\,\text{FORGP} + \beta_{5(3)}\,\text{EXP} + \beta_{6(3)}\,\text{R\&D} + \beta_{7(3)}\,\text{INFO} + \beta_{8(3)}\,\text{PROT} \\ + \beta_{9(3)}\,\text{OBS} + \sum_{m=1}\beta_{10m(3)}\,\text{IND} + \sum_{n=1}\beta_{11n(3)}\,\text{NAT} + \varepsilon_{(3)} \end{array} \right.$$

where P (COmnlEXT=0) = 1 – P (COmnlEXT=1) – P (COmnlEXT=2) – P (COmnlEXT=3) and the error terms $\varepsilon_{(1)}$, $\varepsilon_{(2)}$ and $\varepsilon_{(3)}$ are assumed to be independent, standard normal, random variables.

Table 12 gives results of the multinomial probit estimates based on the CIS4 dataset on the left hand side and the CIS3 dataset on the right hand side, respectively. Firms that cooperate both at home and abroad (COmnlEXT=3) constitute the most promising situation from the knowledge transfer viewpoint, because these firms channel knowledge through these arrangements within the local environment and at the same time across national borders, thus opening gates for potential knowledge spillovers in both directions. A brief look at the results reveals that these are predominantly large firms, affiliated to a network of other enterprises in

Table 12: Multinomial probit results for COmnlEXT

	CIS4			CIS3		
	COmnlEXT=1	COmnlEXT=2	COmnlEXT=3	COmnlEXT=1	COmnlEXT=2	COmnlEXT=3
Constant	-1.740 (0.087)***	-2.929 (0.126)***	-2.839 (0.095)***	-2.681 (0.121)***	-3.587 (0.174)***	-3.512 (0.124)***
LARGE	0.293 (0.040)***	0.380 (0.065)***	0.723 (0.042)***	0.490 (0.061)***	0.448 (0.092)***	0.974 (0.062)***
MEDIUM	0.071 (0.031)**	0.161 (0.052)***	0.166 (0.036)***	0.272 (0.047)***	0.250 (0.072)***	0.438 (0.051)***
DOMGP	0.227 (0.034)***	0.432 (0.057)***	0.448 (0.038)***	0.349 (0.052)***	0.410 (0.085)***	0.543 (0.055)***
FORGP	-0.024 (0.042)	0.577 (0.059)***	0.366 (0.042)***	0.013 (0.062)	0.623 (0.085)***	0.400 (0.061)***
EXP	-0.098 (0.031)***	0.395 (0.055)***	0.533 (0.037)***	-0.087 (0.047)*	0.621 (0.065)***	0.402 (0.047)***
R&D	0.612 (0.031)***	0.494 (0.053)***	0.941 (0.037)***	0.559 (0.043)***	0.286 (0.063)***	0.684 (0.047)***
INFO	0.123 (0.032)***	0.184 (0.053)***	0.454 (0.034)***	0.109 (0.045)**	0.031 (0.069)	0.394 (0.045)***
PROT	0.288 (0.029)***	0.295 (0.047)***	0.548 (0.031)***	0.177 (0.041)***	0.249 (0.063)***	0.474 (0.042)***
OBS	0.141 (0.030)***	0.093 (0.044)**	0.164 (0.030)***	0.189 (0.040)***	0.202 (0.062)***	0.312 (0.042)***
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Wald χ^2		5,738.86***			2,658.98***	
N		28,623			13,827	

Note: Robust standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

a group and with extensive innovation capabilities, because the predictors came out with highly significant and large coefficients without exception. The main purpose of this model, however, is to highlight the two middle categories of firms with exclusively domestic (COmnlEXT=1) or exclusively foreign (COmnlEXT=2) partners. Again, as can be expected, factors influencing these two outcomes do not differ that much, with the prime exception of the FORGP and EXP predictors.

Being affiliated to a foreign group of firms does not seem to make a significant difference for the propensity to engage exclusively with a domestic partner, which strengthens the previous conclusion that in this sense the innovation strategies of foreign affiliates per se do not tend to alter linkages in the local milieu, at least this is not the prevailing pattern in the data, but on the other hand the organization proximity abroad makes a great deal of difference for the likelihood of exclusively foreign cooperation, for which this effect has the highest magnitude as compared to the other predictors, even higher than the size or R&D capabilities of firms. In other words, foreign ownership does not constrain domestic cooperation, but provides distinct opportunities for international transfer of technology through foreign cooperation, possibly in situations when relevant partners are simply not available in the local environment. Similarly exporting comes out with a very large and highly significant coefficient for having a foreign partner only, so that market proximity rules in this context too, but in contrast simultaneously depresses the odds of having a domestic partner only, even though this effect is very small, and therefore does not merit much attention.

Again, these results underline that cooperation with partners abroad is strongly related to organizational and market proximity to foreign locations. But these general trends might mask significant differences across countries. Could it be that indeed under certain circumstances foreign ownership constrains domestic cooperation of firms, or does not really facilitate the foreign one? Could it be that the R&D capability of firms matters for their attractiveness as partners for domestic cooperation only from a certain threshold of economic development, and that this threshold is substantially different for foreign cooperation? Could it be that the large differences between countries in the aggregate propensity to foreign cooperation detected in the descriptive statistics above can not be really attributed to the national framework conditions per se, but are primarily driven by characteristics of the firms themselves? Should on the other hand distinctly national factors, such as for instance size of the country, be taken much more seriously into account for comparing this data, because firms operating in smaller countries naturally tend to interact more across national borders?

As already discussed above, multilevel modelling is the best framework for examining this kind of contextual hypotheses. Hence, we estimate a multilevel version of the multinomial logit model, which explains the four discrete outcomes given by location of the partner by factors operating at the firm and country levels.[25] COmnlEXT is the dependent variable, the vector of firm-level dummies for LARGE, MEDIUM, DOMGP, FORGP, EXP, R&D, INFO, PROT, OBS are the level-1 predictors, while the vector of country-level indicators GDPCAP, POP and GLOBAL are the level-2 predictors. For the same reason as in the previous multilevel estimate, the set of industry dummies IND is included, but their effects are not allowed to differ across countries. A full specification of this model is the following:

[25] Unfortunately, to the best of my knowledge, multivariate multilevel probit (or logit) models cannot be computed in the general statistical software packages like Stata, SPSS or SAS, and not even in those specialized in multilevel modelling such as HLM or MLwiN, so that we could not estimate the bivariate model above (or the multivariate models presented below) in the multilevel framework.

(5) Level-1 model:

$P\,(COmnlEXT_{ij}{=}k \mid \beta_{j(k)}) = P(k)$
$\text{Log}\,[P(k)/P(0)] = \beta_{0j(k)} + \beta_{1j(k)}\ LARGE_{ij} + \beta_{2j(k)}\ MEDIUM_{ij} + \beta_{3j(k)}\ DOMGP_{ij} + \beta_{4j(k)}\ FORGP_{ij} + \beta_{5j(k)}\ EXP_{ij} + \beta_{6j(k)}\ RDIN_{ij} + \beta_{7j(k)}\ INFO_{ij} + \beta_{8j(k)}\ APP_{ij} + \beta_{9j(k)}\ OBS_{ij} + \sum_{m=1} \beta_{10m(k)}\ IND_i$

Level-2 model:

$$\beta_{0j(k)} = \gamma_{00(k)} + \gamma_{01(k)}\ GDPCAP_j + \gamma_{02(k)}\ POP_j + \gamma_{03(k)}\ GLOBAL_j + u_{0j(k)}$$
$$\beta_{1j(k)} = \gamma_{10(k)} + \gamma_{11(k)}\ GDPCAP_j + \gamma_{12(k)}\ POP_j + \gamma_{13(k)}\ GLOBAL_j + u_{1j(k)}$$
$$\beta_{2j(k)} = \gamma_{20(k)} + \gamma_{21(k)}\ GDPCAP_j + \gamma_{22(k)}\ POP_j + \gamma_{23(k)}\ GLOBAL_j + u_{2j(k)}$$
$$\beta_{3j(k)} = \gamma_{30(k)} + \gamma_{31(k)}\ GDPCAP_j + \gamma_{32(k)}\ POP_j + \gamma_{33(k)}\ GLOBAL_j + u_{3j(k)}$$
$$\beta_{4j(k)} = \gamma_{40(k)} + \gamma_{41(k)}\ GDPCAP_j + \gamma_{42(k)}\ POP_j + \gamma_{43(k)}\ GLOBAL_j + u_{4j(k)}$$
$$\beta_{5j(k)} = \gamma_{50(k)} + \gamma_{51(k)}\ GDPCAP_j + \gamma_{52(k)}\ POP_j + \gamma_{53(k)}\ GLOBAL_j + u_{5j(k)}$$
$$\beta_{6j(k)} = \gamma_{60(k)} + \gamma_{61(k)}\ GDPCAP_j + \gamma_{62(k)}\ POP_j + \gamma_{63(k)}\ GLOBAL_j + u_{6j(k)}$$
$$\beta_{7j(k)} = \gamma_{70(k)} + \gamma_{71(k)}\ GDPCAP_j + \gamma_{72(k)}\ POP_j + \gamma_{73(k)}\ GLOBAL_j + u_{7j(k)}$$
$$\beta_{8j(k)} = \gamma_{80(k)} + \gamma_{81(k)}\ GDPCAP_j + \gamma_{82(k)}\ POP_j + \gamma_{83(k)}\ GLOBAL_j + u_{8j(k)}$$
$$\beta_{9j(k)} = \gamma_{90(k)} + \gamma_{91(k)}\ GDPCAP_j + \gamma_{92(k)}\ POP_j + \gamma_{93(k)}\ GLOBAL_j + u_{9j(k)}$$

where *i* denotes a firm, *j* is a country and *k* is the positive discrete outcome (k = 1, 2 or 3). COmnlEXT=0 is the base category, so that by logic of the multinomial model P (COmnlEXT=0) = 1 – P (COmnlEXT=k). From this follows that there are three sets of fixed effects $\gamma_{00(k)}$ ... $\gamma_{93(k)}$ and three sets of random effects $u_{0j(k)}$ ... $u_{9j(k)}$, of which $\gamma_{00(k)}$ are the estimated grand means of the log-odds of the respective outcome across countries, $\gamma_{01(k)}$, $\gamma_{02(k)}$ and $\gamma_{03(k)}$ are the country effects on these intercepts, $u_{0j(k)}$ indicate that the countries vary around that intercepts, $\gamma_{10(k)}$ ... $\gamma_{90(k)}$ are the estimated means of the firm-level slopes across countries, $\gamma_{11(k)}$ … $\gamma_{93(k)}$ are the cross-level interactions between the firm- and country-level predictors and $u_{1j(k)}$ ... $u_{9j(k)}$ indicate that the firm-level slopes vary not only as a function of the predictors but also as a function of unobserved country effects; all of the random effects are assumed to be sampled from a normal distribution with expected zero mean and variance = σ^2_u.[26]

Table 13 provides the results. To improve interpretability of the estimated effects, as in the previous multilevel estimate, we standardized the level-2 predictors GDPCAP, POP and GLOBAL by deducting mean and dividing by standard deviation, so that these variables appear in the estimate with mean of zero and standard deviation equal to one too, and all of the predictors have a meaningful zero-point. Since the level-2 predictors are in the same units of standard deviation after this transformation, furthermore, we can directly compare magnitude of their coefficients. Again, we estimate this multilevel model only on the CIS4 sample, because the CIS3 dataset does not include enough information to find a reliable solution for this relatively complicated problem.

Let us first consider the intercept effects, which are reported in the top of the table. Several statically significant effects of the country variables on the intercept, hence explaining central tendencies in the data regardless of characteristics of the firms, have been detected for the last two outcomes of exclusively foreign cooperation and simultaneously domestic and foreign cooperation, though none of them came out significant in the first equation on exclusively domestic partners. National framework conditions represented by the GDPCAP, POP and

[26] Note that there are no terms for the level-1 residuals, because for a multinomial outcome the variance is completely determined by the population means, so that these residuals are not separate terms to be estimated.

GLOBAL variables are therefore much more relevant for explaining the propensity of firms to arrangements on cooperation involving a foreign partner, than those that do not.

GDPCAP comes out with a negatively significant effect on the propensity of the last outcome, which suggests that firms located in less advanced countries, such as the new EU member countries, are more likely to combine cooperation with both domestic and foreign partners. Arguably, this confirms the previous finding based on the overall cooperation variable presented above, because one reason for firms to undergo the trouble of cooperating with both could be that there are not enough relevant partners at home. In other words, a relative lack (or a low quality) of domestic partners provokes firms operating in the less advanced environment to search for partners abroad. To the extent that the GDPCAP variable can be understood as a broad proxy for quality of the national innovation system, this result suggests that more frequent cooperation of firms abroad can actually signal a backward national innovation system, which is the exact opposite of how the cooperation variables tend to be interpreted in the existing literature on this topic.

Size of the country, given by the POP variable, is significantly negatively associated to both of the outcomes involving foreign cooperation, which confirms the expectation that firms located in smaller countries are for natural reasons, equivalent to those for higher intensity on trading abroad, relatively more likely to engage with a foreign partner. Essentially, this further illuminates the tendency of firms in the new EU member countries to frequently engage in foreign cooperation, because most of these countries are quite small. In other words, for example, this helps us to understand why in the descriptive overview presented above Estonia, Latvia and Lithuania appeared with much higher frequency of cooperation abroad than Germany, Italy or Romania; leaving other relevant factors aside for the moment. Even though this is not a very relevant policy finding, because there is not much that the government can do about size of the country, this result highlights a major methodological point. Since this national variable clearly matters, the cooperation data should be presented orthogonal to size of the country, if anybody considers deriving relevant policy implications from differences between countries.

GLOBAL that stands for globalization of the economy comes out significantly positively associated to the last two outcomes involving foreign cooperation, which is also well in line with expectations, because firms operating in generally more globalized environment, given either by policy, geography, history or for whatever reason, should be relatively more outward looking in search for their cooperation partners. Furthermore, it should be noticed, that the effect of this variable on the exclusively domestic cooperation is positive too, although not statistically significant at conventional levels, so that globalization does not certainly undermine the appetite of firms for cooperation at home either. A straightforward policy implication from this finding is that fears of destabilizing the domestic innovation system by deepening globalization of the economy do not seem to be supported by evidence provided by this cooperation data.

Statistically significant cross-level interaction effects have been detected mostly in the last equations for firms cooperating both at home and abroad, but rarely for the other two outcomes. Being affiliated to a domestic group of enterprises, given by the DOMGP dummy, facilitates access to external knowledge through cooperation arrangements on innovation relatively more in less advanced and less globalized countries, which indicates that domestic business groups play a central role in national innovation systems like these. Nevertheless, foreign ownership, represented by the FORGP dummy, does not significantly interact with the country variables, which is contradictory to the hypothesis that strategies of foreign affiliates are context specific, even though it should be noticed that the random effects reported at the bottom of the table come out relatively high for this variable, so that indeed there are differences across countries in this effect, although these are not related to the three national variables taken into account here.

Furthermore, the results confirm that the effect of R&D capabilities of firms strongly increases with the development level of the country, at least for the last outcome, which can be interpreted either as the fact that cooperation is more intensive on internal R&D of firms in more developed environment, but also that firms without R&D capabilities cooperate more often in less advanced countries. As already discussed above, the latter interpretation actually suggests that firms in less advanced countries tend to cooperate with other organizations to make up for their limited internal capabilities. For example, a firm might engage in a joint project with a publicly funded laboratory, because the firm does not have enough resources (or just do not want to spend them) to maintain R&D facilities on its own. From a policy perspective, this might look as a favourable situation, if taken out of the context, because the public research infrastructure becomes unutilized for the purpose of innovation, but one needs to be very careful to interpret this as a generally positive outcome, because this might actually reflect deficient capabilities of firms. Again, this shows that more cooperation on innovation does not necessarily indicate a positive trend, which is essential to keep in mind for properly interpreting this data.

Size of the firm, represented by the LARGE and MEDIUM dummies, interacts positively with the GDPCAP national factor in the third equation, which suggests that ceteris paribus larger firms have higher likelihood to cooperate in more advanced countries, which could pick up the fact that in this context the cooperation projects are probably more extensive than in less advanced countries. Also MEDIUM interacts positively with GLOBAL, which indicates scale advantages in the ability of firms to benefit from globalization of the economy for cooperation. Only a single cross-level interaction came out at least modestly significant in the equations on exclusively domestic or foreign cooperation, which is the joint effect of EXP and POP in the first one. Since the sign is positive, this interaction suggests that the generally negative association between exporting and exclusively domestic cooperation is relatively less pronounced in countries with larger population, which is a sensible effect, because larges countries offer more domestic partners. None of the other possible cross-level interactions does look to be very relevant.

So much for what we have been able to explain, but equally insightful in the context of multilevel modeling is the residual variance. Many of the random effects come out quite strong, which indicates that a noticeable part of the diversity across countries remains not accounted for. As already mentioned above, however, the number of countries in the sample is quite small, so that we have to constrain the model to a relatively small set of national predictors. At the same time, other relevant indicators of the national framework conditions that one may rightly point out to be potentially relevant, such as those directly measuring quality of the national research infrastructure, could not have been added in the estimates, because these variables tend to be excessively correlated to the incumbent ones. Finally, the unexplained differences could be driven by idiosyncratic national factors, because countries are different from each other in many qualitative respects. Although we have been able to identify quite strong regularities, there is arguably a limit to how much we can explain by quantitative methods like these. To illuminate the rest is a task for more detailed qualitative research.

Table 13: Multilevel multinomial logit results for COmnlEXT (CIS4)

	(1) COmnlEXT = 1	(2) COmnlEXT = 2	(3) COmnlEXT = 3
<u>Fixed Effects:</u>			
For Intercept$_{ij}$ (β_{0j})			
Intercept$_{ij}$ (γ_{00})	-2.158 (0.184)***	-4.856 (0.246)***	-4.337 (0.225)***
GDPCAP$_j$ (γ_{01})	-0.070 (0.206)	-0.175 (0.220)	-0.562 (0.247)**
POP$_j$ (γ_{02})	-0.351 (0.214)	-0.558 (0.254)**	-0.729 (0.262)**
GLOBAL$_j$ (γ_{03})	0.176 (0.200)	0.466 (0.239)*	0.616 (0.244)**
For LARGE$_{ij}$ slope (β_{1j})			
LARGE$_{ij}$ (γ_{10})	0.337 (0.119)**	0.544 (0.170)***	0.921 (0.080)***
GDPCAP$_j$ (γ_{11})	0.276 (0.145)*	-0.010 (0.193)	0.314 (0.092)***
POP$_j$ (γ_{12})	-0.008 (0.142)	-0.110 (0.209)	-0.051 (0.095)
GLOBAL$_j$ (γ_{13})	0.146 (0.132)	0.316 (0.194)	0.107 (0.090)
For MEDIUM$_{ij}$ slope (β_{2j})			
MEDIUM$_{ij}$ (γ_{20})	0.088 (0.071)	0.298 (0.125)**	0.226 (0.068)***
GDPCAP$_j$ (γ_{21})	0.083 (0.085)	-0.060 (0.135)	0.180 (0.076)**
POP$_j$ (γ_{22})	0.025 (0.082)	-0.133 (0.148)	-0.122 (0.080)
GLOBAL$_j$ (γ_{23})	0.173 (0.080)*	0.237 (0.150)	0.202 (0.079)**
For DOMGP$_{ij}$ slope (β_{3j})			
DOMGP$_{ij}$ (γ_{30})	0.481 (0.085)***	0.640 (0.130)***	0.636 (0.083)***
GDPCAP$_j$ (γ_{31})	-0.160 (0.099)	-0.148 (0.143)	-0.325 (0.096)***
POP$_j$ (γ_{32})	-0.127 (0.092)	0.174 (0.144)	0.156 (0.095)
GLOBAL$_j$ (γ_{33})	0.014 (0.088)	-0.167 (0.151)	-0.250 (0.094)**
For FORGP$_{ij}$ slope (β_{4j})			
FORGP$_{ij}$ (γ_{40})	-0.191 (0.119)	0.919 (0.152)***	0.443 (0.079)***
GDPCAP$_j$ (γ_{41})	-0.067 (0.148)	0.020 (0.170)	-0.124 (0.092)
POP$_j$ (γ_{42})	0.083 (0.145)	0.181 (0.185)	0.067 (0.096)
GLOBAL$_j$ (γ_{43})	-0.087 (0.134)	-0.050 (0.178)	0.000 (0.092)
For EXP$_{ij}$ slope (β_{5j})			
EXP$_{ij}$ (γ_{50})	-0.332 (0.083)***	0.713 (0.130)***	0.735 (0.080)***
GDPCAP$_j$ (γ_{51})	0.038 (0.096)	0.139 (0.127)	0.009 (0.088)
POP$_j$ (γ_{52})	0.230 (0.097)**	-0.219 (0.157)	0.034 (0.095)
GLOBAL$_j$ (γ_{53})	-0.051 (0.093)	-0.126 (0.148)	-0.150 (0.092)
For R&D$_{ij}$ slope (β_{6j})			
R&D$_{ij}$ (γ_{60})	0.620 (0.111)***	0.593 (0.130)***	1.343 (0.092)***
GDPCAP$_j$ (γ_{61})	0.109 (0.137)	0.166 (0.147)	0.420 (0.111)***
POP$_j$ (γ_{62})	0.162 (0.137)	-0.102 (0.159)	-0.053 (0.119)
GLOBAL$_j$ (γ_{63})	-0.026 (0.127)	-0.047 (0.147)	-0.200 (0.105)*
For INFO$_{ij}$ slope (β_{7j})			
INFO$_{ij}$ (γ_{70})	0.140 (0.100)	0.178 (0.138)	0.614 (0.111)***
GDPCAP$_j$ (γ_{71})	0.105 (0.120)	-0.292 (0.152)*	0.070 (0.131)
POP$_j$ (γ_{72})	-0.063 (0.122)	0.097 (0.172)	-0.043 (0.136)
GLOBAL$_j$ (γ_{73})	-0.069 (0.114)	-0.017 (0.167)	-0.145 (0.130)
For PROT$_{ij}$ slope (β_{8j})			
PROT$_{ij}$ (γ_{80})	0.271 (0.092)**	0.438 (0.127)***	0.667 (0.078)***
GDPCAP$_j$ (γ_{81})	-0.071 (0.109)	-0.012 (0.143)	0.133 (0.090)
POP$_j$ (γ_{82})	0.177 (0.110)	0.165 (0.153)	0.192 (0.094)*
GLOBAL$_j$ (γ_{83})	-0.021 (0.105)	-0.251 (0.150)	-0.004 (0.091)

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For OBS_{ij} slope (β_{9j})			
OBS_{ij} (γ_{90})	0.175 (0.070)**	0.026 (0.112)	0.209 (0.062)***
$GDPCAP_{j}$ (γ_{91})	0.055 (0.083)	-0.130 (0.125)	0.112 (0.071)
POP_{j} (γ_{92})	-0.012 (0.084)	0.235 (0.137)	-0.065 (0.074)
$GLOBAL_{j}$ (γ_{93})	-0.036 (0.079)	-0.054 (0.134)	-0.065 (0.073)
Industry dummies (β_{10m})	Yes	Yes	Yes
Random effects:			
$Intercept_{ij}$ (u_{0j})	0.624	0.573	0.748
$LARGE_{ij}$ slope (u_{1j})	0.348	0.418	0.168
$MEDIUM_{ij}$ slope (u_{2j})	0.172	0.276	0.158
$DOMGP_{ij}$ slope (u_{3j})	0.207	0.190	0.217
$FORGP_{ij}$ slope (u_{4j})	0.353	0.374	0.178
EXP_{ij} slope (u_{5j})	0.241	0.215	0.214
$R\&D_{ij}$ slope (u_{6j})	0.367	0.274	0.242
$INFO_{ij}$ slope (u_{7j})	0.310	0.342	0.378
$PROT_{ij}$ slope (u_{8j})	0.282	0.332	0.232
OBS_{ij} slope (u_{9j})	0.196	0.267	0.160
Level-1 observations		28,623	
Level-2 groups		15	

Note: Non-linear unit-specific model with the logit link function; restricted maximum likelihood (PQL) estimate; coefficients and standard errors in brackets reported for the fixed effects; standard deviations reported for the random effects; *, **, *** denote significance at the 10, 5 and 1 percent levels.

5.3 Cooperation arrangements with different types of partners: Are they compatible?

To further deepen the analysis, we explore the heterogeneity of cooperation by the type of partners. Unlike in the previous section, where we estimated the bivariate probit model for two correlated binary outcomes, we examine a situation with more than two correlated outcomes, which requires the multivariate probit model. COtotSUP, COtotCUS, COtotCOM, COtotINS, COtotUNI and COtotGMT dummies for cooperation with each of the six types of external partners are the dependent variables.

If we estimated separate univariate models for each of the six dummies, we would ignore the possibility that the decisions of firms to cooperate with the different types of partners might be related to each other. To allow for their correlation, we predict probability of the six outcomes jointly in the multivariate framework as follows:

(6) $$P\,(CO_{(k)} = 1 \mid \beta_{(k)}) = \beta_{0(k)} + \beta_{1(k)}LARGE + \beta_{2(k)}MEDIUM + \beta_{3(k)}DOMGP + \beta_{4(k)}FORGP + \beta_{5(k)}EXP + \beta_{6(k)}R\&D + \beta_{7(k)}INFO + \beta_{8(k)}PROT + \beta_{9(k)}OBS + \sum_{m=1}\beta_{10m(k)}\,IND + \sum_{n=1}\beta_{11n(k)}\,NAT + \varepsilon_{(k)}$$

where k refers to the six types of partners (k = 1 ... 6 = COtotSUP, COtotCUS, COtotCOM, COtotINS, COtotUNI and COtotGMT), hence $\varepsilon_{(k)}$ denotes six residuals ($\varepsilon_{(1)}$ ... $\varepsilon_{(6)}$) sampled from the multivariate normal distribution that are assumed to be correlated with each other, so that there is covariance matrix V with values of 1 on the leading diagonal and these correlations $\rho_{xk} = \rho_{kx}$ as off-diagonal elements. Similarly to the bivariate probit model, we can therefore test a hypothesis that their correlation is equal to zero ($\rho_{xk} = \rho_{kx} = 0$), which allows us to examine the interdependence between the different types of cooperation. If the correlation is positive, the propensity for a positive outcome on one type of the partner tends to increase simultaneously with the other. If the correlation turns out to be negative, the opposite tendency has been detected.

Tables 14.1 and 14.2 provide results of the multivariate probit estimates based on the CIS4 and CIS3 samples, respectively.[27] Most of the predictors, with only a few exceptions that tend to prove the rule, are highly statistically significant across the board. To the extent that there are noticeable differences in magnitude of the estimated coefficients, these mainly follow the divide between other firms (suppliers, customers or competitors) versus research organizations (consultants, research institutes and universities) as the partners for cooperation. For example, the latter seem to be slightly more demanding on resources, capabilities and perceptions of firms with regards the innovation process (R&D, INFO, PROT and OBS), but the differences are relatively small.

[27] Cappellari and Jenkins (2003) provide extension of the bivariate probit model for more than two dependent variables, which has been used to estimate the multivariate probit model in Stata 9.2.

Table 14.1: Multivariate probit by the type of partner (CIS4)

	(1) COtotSUP	(2) COtotCUS	(3) COtotCOM	(4) COtotINS	(5) COtotUNI	(6) COtotGMT
Constant	-1.236 (0.055)***	-1.713 (0.059)***	-1.930 (0.069)***	-1.772 (0.065)***	-2.096 (0.065)***	-1.891 (0.068)***
LARGE	0.363 (0.026)***	0.193 (0.028)***	0.278 (0.031)***	0.348 (0.030)***	0.446 (0.029)***	0.355 (0.035)***
MEDIUM	0.105 (0.021)***	-0.013 (0.023)	-0.003 (0.026)	0.067 (0.024)***	0.128 (0.025)***	0.057 (0.030)*
DOMGP	0.237 (0.023)***	0.223 (0.024)***	0.150 (0.027)***	0.239 (0.026)***	0.247 (0.026)***	0.202 (0.030)***
FORGP	0.206 (0.027)***	0.225 (0.029)***	0.085 (0.031)***	0.172 (0.030)***	0.161 (0.030)***	0.132 (0.036)***
EXP	0.071 (0.021)***	0.176 (0.023)***	0.032 (0.026)	0.113 (0.025)***	0.167 (0.026)***	0.136 (0.030)***
R&D	0.405 (0.022)***	0.516 (0.024)***	0.436 (0.026)***	0.508 (0.026)***	0.673 (0.027)***	0.559 (0.033)***
INFO	0.184 (0.021)***	0.206 (0.023)***	0.234 (0.024)***	0.227 (0.024)***	0.241 (0.024)***	0.216 (0.028)***
PROT	0.260 (0.019)***	0.260 (0.021)***	0.216 (0.023)***	0.264 (0.022)***	0.334 (0.022)***	0.343 (0.025)***
OBS	0.096 (0.018)***	0.132 (0.020)***	0.128 (0.021)***	0.109 (0.021)***	0.132 (0.021)***	0.107 (0.025)***
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
ρ_{2k}	0.754 (0.007)***					
ρ_{3k}	0.659 (0.009)***	0.715 (0.008)***				
ρ_{4k}	0.668 (0.009)***	0.658 (0.008)***	0.643 (0.009)***			
ρ_{5k}	0.596 (0.010)***	0.639 (0.009)***	0.607 (0.010)***	0.683 (0.009)***		
ρ_{6k}	0.583 (0.012)***	0.637 (0.011)***	0.612 (0.011)***	0.682 (0.010)***	0.778 (0.008)***	
Wald χ^2	7,502.36***					
N	28,623					

Note: Robust standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table 14.2: Multivariate probit by the type of partner (CIS3)

	(1) COtotSUP	(2) COtotCUS	(3) COtotCOM	(4) COtotINS	(5) COtotUNI	(6) COtotGMT
Constant	-1.962 (0.078)***	-2.199 (0.083)***	-2.500 (0.100)***	-2.178 (0.086)***	-2.393 (0.091)***	-2.737 (0.099)***
LARGE	0.465 (0.040)***	0.368 (0.041)***	0.350 (0.045)***	0.523 (0.042)***	0.592 (0.044)***	0.632 (0.047)***
MEDIUM	0.245 (0.032)***	0.168 (0.033)***	0.217 (0.037)***	0.241 (0.035)***	0.255 (0.037)***	0.341 (0.039)***
DOMGP	0.312 (0.035)***	0.305 (0.036)***	0.272 (0.041)***	0.320 (0.037)***	0.307 (0.038)***	0.278 (0.040)***
FORGP	0.281 (0.040)***	0.209 (0.041)***	0.197 (0.045)***	0.250 (0.042)***	0.134 (0.045)***	0.053 (0.047)
EXP	0.138 (0.030)***	0.180 (0.032)***	0.075 (0.035)**	0.089 (0.032)***	0.221 (0.033)***	0.160 (0.036)***
R&D	0.308 (0.029)***	0.383 (0.031)***	0.403 (0.036)***	0.409 (0.032)***	0.575 (0.036)***	0.536 (0.039)***
INFO	0.185 (0.030)***	0.156 (0.031)***	0.186 (0.033)***	0.222 (0.031)***	0.224 (0.032)***	0.197 (0.034)***
PROT	0.215 (0.028)***	0.186 (0.028)***	0.152 (0.032)***	0.256 (0.029)***	0.223 (0.030)***	0.198 (0.032)***
OBS	0.119 (0.028)***	0.181 (0.028)***	0.139 (0.031)***	0.168 (0.029)***	0.191 (0.030)***	0.193 (0.032)***
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
ρ_{2k}	0.763 (0.009)***					
ρ_{3k}	0.723 (0.011)***	0.774 (0.010)***				
ρ_{4k}	0.736 (0.010)***	0.718 (0.010)***	0.725 (0.011)***			
ρ_{5k}	0.678 (0.012)***	0.687 (0.011)***	0.676 (0.012)***	0.728 (0.011)***		
ρ_{6k}	0.649 (0.013)***	0.659 (0.013)***	0.659 (0.014)***	0.707 (0.012)***	0.783 (0.010)***	
Wald χ^2	3,429.88***					
N	13,827					

Note: Robust standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

The main result of this exercise can be found in the lower part of the table, where correlations between the residuals are reported. All of them are strongly positive and highly statistically significant, which indicates that the dependent variables are closely linked to each other. As already discussed above, these correlations might be positive due to complementary nature of the different types of cooperation but also due to omitted predictors jointly affecting them, but we side with the former, because many relevant predictors have been accounted for and their relations come out to be very strong. Even after controlling for a battery of relevant explanatory variables in the multivariate framework, we confirm the finding derived from the exploratory factor analysis above that there seems to be a strong tendency of firms to be generally cooperative or not, regardless of the type of partners.

6. Conclusions

Using large micro datasets from the Third and Fourth Community Innovation Surveys in sixteen European countries, we examined the propensity of firms to cooperate on innovation with domestic as compared to foreign partners, with different types of organizations and how these patterns differ across countries. Econometric estimates of univariate, multivariate and multinomial probit (or logit) models, including their multilevel variants, revealed significant heterogeneity of the effects of organization and market proximity and substantial differences in some of these relationships between countries. More specifically, the main results can be summarized as follows.

Strong complementarities have been detected between cooperation of firms on innovation with domestic and foreign partners. Firms do not choose between cooperating at home or abroad, they most often combine both, so that fears of hollowing out of the local innovation milieu by increasingly globalized interactions of firms in the innovation process are not justified by the results. Also the decisions of firms to cooperate with the various types of cooperation partners is closely correlated to each other, because most firms simultaneously combine knowledge from multiple external sources.

Scale advantages, innovation capabilities and affiliation to a domestic group boost cooperation of firms in the innovation process, regardless of whether the partner organization is located at home or abroad. Organizational proximity abroad, given by affiliation to a group with headquarters abroad, facilitates international knowledge transfer through cooperation on innovation with external foreign partners, but does not seem to undermine linkages of foreign affiliates in the host country. Similarly market proximity to foreign customers promotes access to partners for cooperation abroad, but does not make much difference for the propensity of firms to cooperate at home. Global activities of firms do not constrain their local relations.

Significant differences have been found between countries at different levels of development, particularly in the propensity to foreign cooperation. Surprisingly, firms located in less advanced countries appear more cooperative on innovation, even after controlling for a variety of other relevant effects in the multilevel econometric framework. Size of the country is for natural reasons, equivalent to those for lower propensity to foreign trade, negatively associated to the frequency of foreign cooperation, hence this data should be interpreted orthogonal to size of the country, if anybody considers deriving relevant policy recommendations. Globalization of the national economic system, given by trade, foreign direct investment and foreign licensing, makes firms relatively more outward looking in cooperation on innovation, but does not weaken their local links, which further supports the conclusion that globalization does not destabilize the local systemic interactions. Moreover, there is a substantial variability of the micro effects across countries, which highlights sensitivity of the firms to national framework conditions. Organizational proximity to other firms tends to be much more intimately related to cooperation on innovation in those operating in less advanced countries, whereas the effects of internal capabilities of firms, especially R&D, broadly follow the opposite tendency.

But the results also reveal that the context matters for interpretation of the cooperation variables themselves, because these arrangements in less advanced countries may actually more than anything else indicate limited internal capabilities of firms and a lack of relevant local partners for domestic cooperation, so that evidence on cooperation behaviour of firms should be used in comparative studies, such as the European Innovation Scoreboard, with a great caution. Finally, there are significant unexplained random differences across countries, which could be driven by idiosyncratic national factors, because countries are different from each other in many qualitative respects. Although we have been able to identify relatively strong national regularities, there is obviously a limit to how much we can ever explain by quantitative methods like these.

From the methodological perspective, however, the paper shows how cross-country comparative research can be conducted by using data directly at the firm-level. Analysis of the pan-European dataset gave us a unique opportunity to compare results of the very same model in countries at widely different levels of economic development. And we have shown that this approach can yield important insights into the differences how activities of multinational firms affect advanced and less advanced countries. As new micro datasets with data harmonized across many countries become increasingly available for research purposes from Eurostat and elsewhere, it becomes a major opportunity for future research to put forward more comparative evidence of this kind.

As already mentioned above, a major limitation of this analysis is that not much could have been done about a potential endogeneity of the estimated coefficients due to a lack of valid instruments in the dataset. Any interpretation in terms of causality between the explanatory and dependent variables should be therefore put forward with caution. Another related limitation given by the dataset in hand is the cross-sectional nature of the analysis, because the datasets could not be connected due to confidentiality of the respondents. It remains an important challenge for future research to address these caveats if better data become available in the future.

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Appendix 1: Correlation matrix between the firm-level predictors

		LARGE	MEDIUM	DOMGP	FORGP	EXP	R&D	INFO	PROT	OBS
CIS4	LARGE	1.00								
	MEDIUM	-0.32	1.00							
	DOMGP	0.21	0.07	1.00						
	FORGP	0.21	0.07	-0.25	1.00					
	EXP	0.12	0.13	0.04	0.15	1.00				
	R&D	0.12	0.06	0.15	0.03	0.23	1.00			
	INFO	0.01	-0.01	0.00	-0.04	0.03	0.05	1.00		
	PROT	0.16	0.03	0.13	0.03	0.19	0.24	0.05	1.00	
	OBS	-0.08	-0.04	-0.07	-0.10	0.02	0.05	0.09	0.01	1.00
CIS3	LARGE	1.00								
	MEDIUM	-0.29	1.00							
	DOMGP	0.16	0.09	1.00						
	FORGP	0.24	0.07	-0.22	1.00					
	EXP	0.12	0.10	0.02	0.14	1.00				
	R&D	0.12	0.05	0.10	0.04	0.12	1.00			
	INFO	-0.01	-0.01	-0.02	-0.07	0.00	0.07	1.00		
	PROT	0.15	0.07	0.08	0.09	0.10	0.24	0.09	1.00	
	OBS	-0.08	-0.05	-0.01	-0.10	-0.03	0.05	0.09	0.02	1.00